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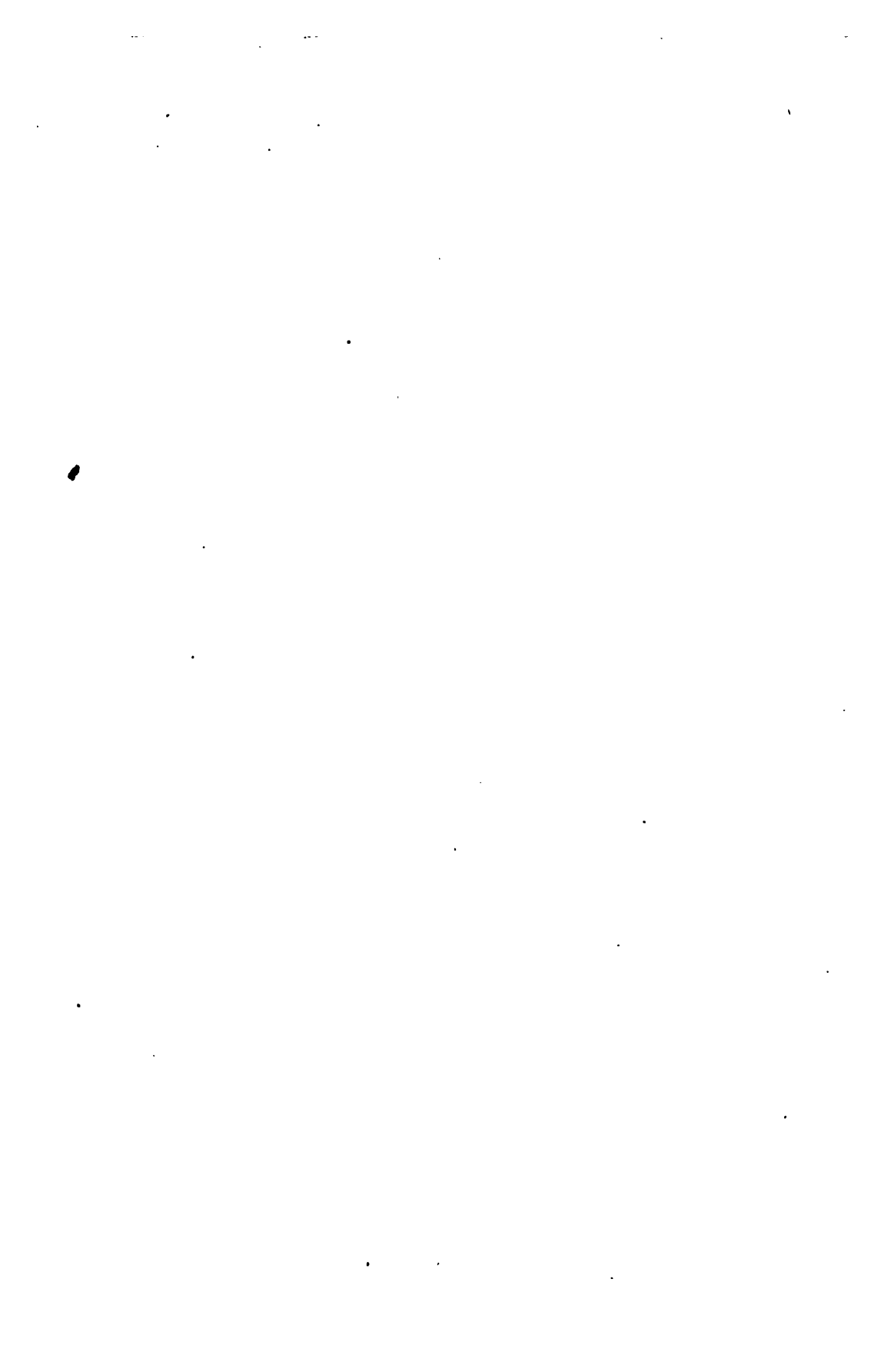
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New in Press,

GREGORY'S ORGANIC CHEMISTRY:

FOURTH AMERICAN

FROM THE FOURTH LONDON EDITION.

EDITED BY

J. MILTON SANDERS, M. D., LL. D.

PROFESSOR OF CHEMISTRY

IN THE ECLECTIC MEDICAL INSTITUTE OF CINCINNATI.

THE ABOVE WORK WILL BE READY IN NOVEMBER.

Anal. p. 11.

©

HANDBOOK
OF
INORGANIC CHEMISTRY;
FOR THE USE OF STUDENTS.

BY WILLIAM GREGORY, M.D., F.R.S.E.

PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF EDINBURGH, AND
AUTHOR OF "HANDBOOK OF ORGANIC CHEMISTRY."

FOURTH AMERICAN
FROM THE THIRD ENGLISH EDITION.

TO WHICH IS ADDED

©

THE PHYSICS OF CHEMISTRY,

BY J. MILTON SANDERS, M.D., LL. D.

PROFESSOR OF CHEMISTRY IN THE ECLESIOTIC MEDICAL INSTITUTE OF CINCINNATI; MEMBER
OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, ETC.

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TO THE
MEMBERS
OF THE
AMERICAN ASSOCIATION
FOR
THE ADVANCEMENT OF SCIENCE,
THIS
American Edition
OF
DR. GREGORY'S INORGANIC CHEMISTRY
IS INSCRIBED.

PREFACE

TO THE FOURTH AMERICAN EDITION

OF

GREGORY'S INORGANIC CHEMISTRY.

THE original work of Professor Gregory does not contain the *Imponderables*, a very important department of modern Chemistry. The first American edition, like the European, was therefore devoid of *Light, Heat, and Electricity*, an oversight which was felt by those many American professors who have adopted this work in their colleges, as one which was almost inexcusable. While the aspirant for the medical profession in Europe has universally gone through the initiatory study of General Physics, the student in this country is seldom provided with such an education; but too often directly from the plow or the workshop—whither he has probably earned the money to pay his college tuition—he takes his seat in the medical college, prepared to derive all the knowledge necessary to make him an accomplished physician from the professors of the institution. So far as Chemistry and Physics are concerned, this task devolves upon the Professor of Chemistry, and therefore the work which he adopts in his class must necessarily contain the subjects of *Light, Heat, and Electricity*. In fact, these branches of knowledge have now become an inseparable department of modern Chemistry, not only in their relations to general Chemistry, but to Medicine. Such considerations as these, rendered it obligatory upon the American editor to supply the matter indispensably necessary to perfect this work. He has accomplished the task to the best of his ability, so far as the limited space allotted him for that purpose will admit.

In the present advanced state of chemical science, when so many accomplished persons are daily exploring its wide domains, and culling such rich matter from them, to pretend to compose an original work upon either of the departments of chemical science, would be but to perpetrate an insult upon the understanding of the intelligent reader. Whilst the matter prefixed to this invaluable work of Professor Gregory cannot be designated a compilation (the greater portion of it being written in the language of the editor), it still cannot aspire to the dignity of an original composition. The writer

has not hesitated to make free use of the works of the ablest physicists of the age, not failing to give each person credit for whatever he may have originated, when that could be satisfactorily obtained. This is, however, no easy task, as the greater number of modern works upon Physics and Chemistry, although prolific upon the subjects of modern discoveries, are too barren in regard to their originators.

The entire subject of the Imponderables is condensed as much as possible, therefore the writer has not thought it expedient to insert the many long and prolix tables upon the subject of heat which the large works upon Physics contain. He has confined himself simply to the annunciation of the laws which govern LIGHT, HEAT, and ELECTRICITY, together with such matter as may be of the greatest importance to the student in the acquisition of a general knowledge of these sciences. For the more prolix and recondite matter upon these subjects, the student is referred to the large works devoted especially to them. At the same time, we venture the assertion, that in the condensed matter contained in this volume, the student will not fail to find the laws of these sciences, and the principal facts associated with their revelation, clearly explained.

To speak in praise of Professor Gregory's work upon Chemistry proper, would be wholly superfluous, as it is used as a text-book in the principal medical colleges and universities in England and the United States, and in a translated form in the French and German universities. Although highly condensed, still the student will find that it is quite complete; while the processes for the preparation of the various substances are characterized for their brevity and perspicuity. This Inorganic Chemistry of Dr. Gregory is therefore offered to the chemists, teachers, and physicians of the United States as a condensed treatise upon the science, while this condensation really relates more to words than to matter, for it comprises within its few hundred pages a complete treatise upon the doctrines of Inorganic Chemistry.

In conclusion, the editor would return his thanks to several friends for their valuable suggestions and assistance, especially to Dr. Joseph H. Wilson, of New York. J. M. S.

New York, September, 1854.

PUBLISHERS' NOTICE.

THE delay in the publication of the fourth edition of this work, proceeded from the retarded sale of the former editions, occasioned by the want of *THE PHYSICS OF CHEMISTRY*, which is not contained in Gregory's work, and which is indispensable to an American edition. The publishers are now happy to inform the public that this great retardation to what would otherwise have rendered this work most complete has been supplied by *PROFESSOR J. MILTON SANDERS*. This renders Gregory's *Chemistry* the most valuable extant, both in the arrangement, in the elucidation of its matter, and in the felicitous style of its illustration. Perhaps no person has succeeded so admirably as Dr. Gregory in the accomplishment of condensation, without the sacrifice of perspicuity, and this is what has rendered his work so popular, especially among those whose duty it is to teach the science. It is especially this class of persons who are most cognizant of the almost insurmountable difficulty of condensing and arranging the vast mass of chemical knowledge accumulated at the present day into one small volume of a few hundred pages. This great task Dr. Gregory has accomplished, and this volume is the result of his labors in the Inorganic department of the science. It is therefore offered to the public as the ablest exposition of modern chemical science extant (when taken in conjunction with the volume on *Organic Chemistry*), and is therefore calculated for the general student, as well as for those who are devoting their time to the acquisition of medical science.

NEW YORK, September, 1854.

INORGANIC CHEMISTRY.

L I G H T.

THE PHYSICAL PROPERTIES OF LIGHT; OR THE PHYSICS OF LIGHT.

UNTIL the time of Sir Isaac Newton, but little was known of the nature of light. That great philosopher proved that light does not present—in the language of one who lived before him—"an instance of homogeneity," but that it is really of a composite nature, and constituted of even more distinct energies than he supposed.

Light is imponderable, or at least is not susceptible of being weighed on our most delicate balances. It is in the highest degree expansible, and spreads itself out from its point of origin in rays which traverse space with great velocity. Its intensity varies inversely as the square of the distance from the luminous body. It is the agent which produces vision. Its phenomena are explained either on the supposition that it is a material fluid of extreme attenuation, emanating in corpuscles from a luminous body; or that it is produced by the undulations of a "luminiferous medium," set in motion by the incandescent body. The former is termed the theory of *Emanations*, and originated in its present signification with Sir Isaac Newton. The latter is termed the theory of *Undulations*, and receives its greatest support from the philosophers of England.

Light passes through the air, and all other *transparent* bodies, with greater or less facility. It is entirely retarded by *opaque* bodies, unless they consist of extremely thin laminae.

When light falls upon other bodies, either transparent or opaque, it is thrown off or *reflected*. The incident and reflected rays form equal angles with the surface from which the light is reflected.

If a ray of light is passed near to a dense body, its course is altered. It is then said to be *inflected*, or it undergoes a *bending* or *inflection*.

When a ray of light passes obliquely from a rarer to a denser medium, it is bent from its direct course, or is said to be *refracted*.

This also happens if the ray passes from a dense medium into one which is lighter, but in the latter case the ray takes a different direction from that in the former. In the case of the passage of the ray into the denser medium, the ray is bent towards the perpendicular, and *vice versa*. Inflexion and Refraction may be accounted for by the supposition, that the attraction and adhesion of bodies for light increase with their density and combustibility. (Gmelin.)

By refraction the luminous beam is resolved into three colored rays, which are *blue*, *yellow*, and *red*. The yellow ray is the most luminous, while the red ray is the most heating. Beyond the violet, there is a faint lavender gray color. These colored rays are not farther effected by a second refraction.

Beyond the violet, there are a series of rays termed the *actinic* or *chemical rays*. They are the most refrangible of all the rays.

When light falls upon bodies at a particular angle (35° for glass), the reflected ray is possessed of properties which do not belong to the incident ray. It is said to be *polarised*. This polarisation of light also takes place when the ray is passed through several media, especially through crystals not belonging to the regular system. In this case the ray is separated into two rays, which are oppositely polarised.

THE REFRACTION OF LIGHT.

We will now explain the refraction of light. When a ray of light passes from one transparent medium into another of a different density, it is bent out of its course, the direction of the ray changing both at the surface where it enters, and at that where it leaves. If the ray passes from a rarer into a denser medium, then it is bent towards the perpendicular, and *vice versa*. But for this fact, which to many persons might at first appear a subject of regret, as preventing the distinct vision of objects through all transparent media, light could have been of little utility to man. There could have been neither lenses as now, nor any optical instruments, as telescopes and microscopes, of which lenses form a part, nor even the eye itself. (Arnot.)

If the rays of light fall perpendicularly upon a transparent medium, they pass through without being refracted, or bent from the original line of their direction. If a ray of light from *k* fall perpendicularly to the surface of the piece of glass at *e* (Fig. 1), it will go on to *h* in the right line *k e o g h*. But if the same ray be directed to the surface *e* obliquely, as from *a*, instead of passing through in a direct line to *b*, in the direction *a e m b*, it will be refracted to *d* in a direction approaching nearer to the perpendicular line *k h*. The ray *a e* is termed the *ray of incidence*, or the *incident ray*, and the angle *a e k* which it makes with the perpendicular *k h* is called the *angle of incidence*. That part of the ray from *e* to *d* passing through the transparent medium, is called the *ray of refraction*, or the *re-*

fracted ray; and the angle $d e g$ which it makes with the perpendicular is called the *angle of refraction*. The ray projected from a to e , and refracted to d , in passing out of the transparent medium, as at d , is as much bent from the line of the refracted ray $e d$ as that was from the line of the original ray $a e b$. It follows, then,

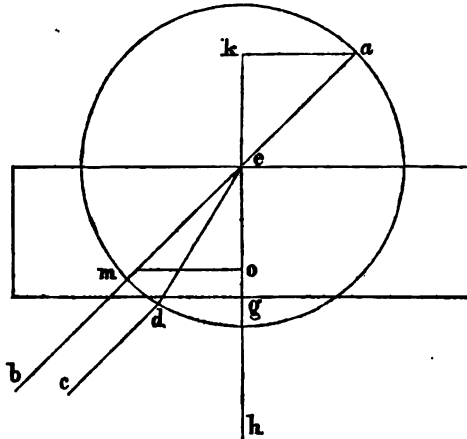


Fig. 1.

that any ray passing through a transparent medium, whose two surfaces—the one at which the ray enters, and the one at which it passes out—are parallel planes, is first refracted from its original course, but in passing out is bent into a line parallel to, and running in the same direction as the original line, the only difference being that its course at this stage is shifted a little to one side of that of the original. If from the centre e a circle be described with any radius, as $d e$, the arc $g m$ measures the *angle of incidence* $g e m$, and the arc $g d$ the *angle of refraction* $g e d$. A line $m o$, drawn from the point m perpendicular to $h k$, is called the *sine* of the angle of incidence, and the line $d g$ the *sine* of the angle of refraction. From the conclusions drawn from the principles of geometry, it has been found, that in any particular transparent substance, the sine of the angle of incidence $m o$ has always the same ratio to the sine $d g$ of the angle of refraction, no matter what be the degree of obliquity with which the ray of incidence $a e$ is projected to the surface of the transparent medium.

If the ray of incidence passes from air obliquely into water, the sine of incidence is to that of refraction as 4 to 3; if it passes from air into glass, the proportion is 3 to 2; and if from air into diamond, it is as 5 to 2. (Hogg.)

REFRACTION OF LIGHT THROUGH LENSES.

Fig. 2 represents the various forms of lenses; *a* is a plain lens, or a plain piece of glass of equal thickness; *b* is termed a concavo-con-

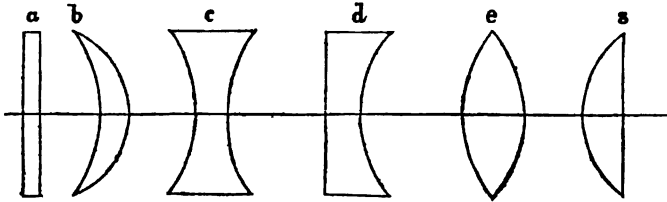


Fig. 2.

convex lens, or a meniscus; *c* is a bi-concave, or double concave lens; *d* is a plano-concave lens; *e*, a double convex or bi-convex lens; *f* is a plano-convex lens. The line passing through the lenses perpendicular to their two surfaces is termed the *axis* of the lens. The point at which the object is best seen through the lens is called its *focus*, and the distance from the middle of the lens to that focus is termed the *focal length* or distance. The point where the axial line cuts the surface of the lens is called the *vertex*; the middle point between them is termed the *centre*, and the distance between them the *diameter*.

When parallel rays (Fig. 3) fall upon a double-convex lens *l l'* parallel to its axis *r' f'*, the ray *r' c*, which coincides with the axis, will pass through without suffering any refraction; but the other rays *r l*, *r'' l'*, will be refracted at each of the surfaces of the lens, and the refracted rays corresponding to them, namely *l f'*, *l' f''*, will be found to meet at some point *f'* in the axis. But when the rays are oblique to the axis, as *s l*, *s'' l'*, *t l*, *t'' l'*, the rays *s' c*, *t' c*, which pass through the centre *c* of the lens, will suffer refraction at each surface; but as the two refractions are equal, and in opposite directions, the finally refracted rays *c f*, *c f'* will pass from *s' c*, *t' c*, and it will be found that *s l*, *s'' l'* will be refracted to a common point *f''*, in the direction of the central ray *s' f'*, and *t l*, *t'' l'* to the point *f*. When the lens is of glass, and equally convex, the focal distance will be equal to the radius. As each ray carries with it the image of the object from whence it proceeds, it follows that if those rays, after intersecting each other, and having formed an image at their intersection, are again united by refraction or reflection, they will form a new image, and that repeatedly, so long as their order is not disturbed. It follows also that when the progress of the luminous ray is under consideration, we may look upon the image as the object, and the object as the image, and consider the second image, as if it had been produced by the first, as an object,

and so on. This is one of the principles involved in the adaptation of these lenses to magnifying objects. It has been shown in Fig. 8

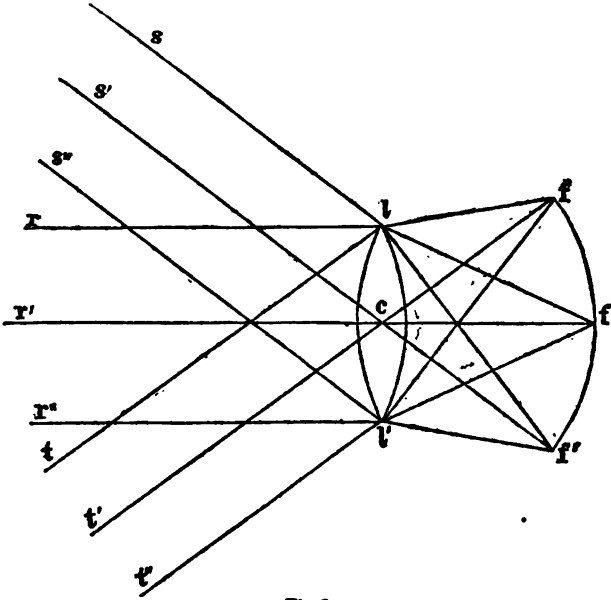


Fig. 3.

that if the point of light be situated above the line of the axis, the focus will then be below it, and *vice versa*; but the surface of every luminous body may be regarded as comprehending an infinite number of such points, from all of which a pencil of light-rays proceeds, and is refracted according to the general law, so that a perfect but inverted image or picture of the object is formed upon any surface placed in the focus, and adapted to receive the rays.

And if the object be placed at twice the distance of the principal

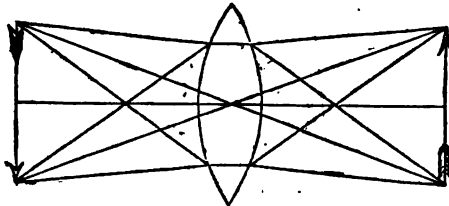


Fig. 4.

focus, the image being formed at an equal distance on the other side of the lens, will be of the same dimensions with the object, as in Fig. 4; but if the object is placed nearer to the lens, the image will be farther from it, and of larger dimensions, as in Fig. 5; and,

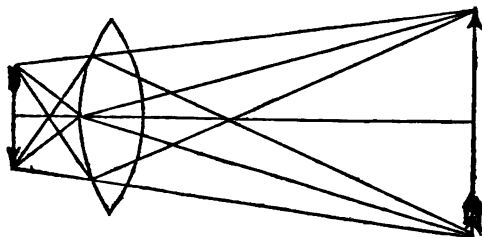


Fig. 5.

on the other hand, if the object be farther from the lens, the image will be nearer to it, and smaller than itself.

But it is to be observed, that the larger the image is in proportion to the object, the less bright it will be, because the same amount of light has to be spread over a greater surface; whilst a smaller image will be much more brilliant. (Hogg.)

It is at the surfaces of bodies that the deflection takes place, while the ray of light passes through the medium in straight lines. That is, upon entering at one surface, the ray is bent out of its course, and it is again bent upon leaving the other surface. From this, and the foregoing, it is evident that, by modifying the surfaces of media, the ray of light may be diverted in almost any direction.

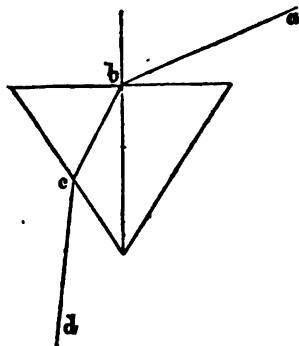


Fig. 6.

This is illustrated in Fig. 6, where refraction takes place through a prism.

The ray *a* in the above figure passes in an oblique direction into the prism. At the surface *b*, or where it enters, it is deflected to *c*. Here, in passing out of the prism, it undergoes another deflection, and passes off in the direction of *d*.

In Fig. 7 there are two prisms placed together with their bases in contact. An inspection merely will give the reader a clear idea of the direction the rays take in passing through them.

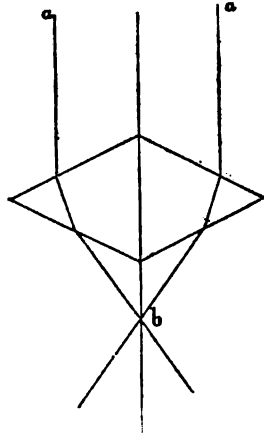


Fig. 7.

It will be perceived from the above figure that when two prisms are placed base to base, parallel rays of light *a a* are refracted to a point or focus *b*. This is analogous to a double or bi-convex lens. When the prisms are placed edge to edge, then the rays of

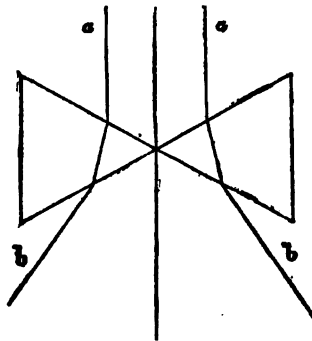


Fig. 8.

light are diverted farther asunder, or from the perpendicular, as is illustrated in Fig. 8. Prisms arranged in this way illustrate the passage of light through a double-concave lens.

THE SPHERICAL ABERRATION OF LENSES.

The optician has several disadvantages to contend against in the construction of his lenses. One of them, and perhaps the most serious one, is that of *spherical aberration*. It will be perceived that the rays which pass through the lens near to its axis, are brought to a focus farther from the lens than those which pass through its circumferential portion. This is illustrated in Fig. 9, where the rays *a b* are passing through the lens near the circumference, and are converged to a focus at *f*. The rays *a' a''* and

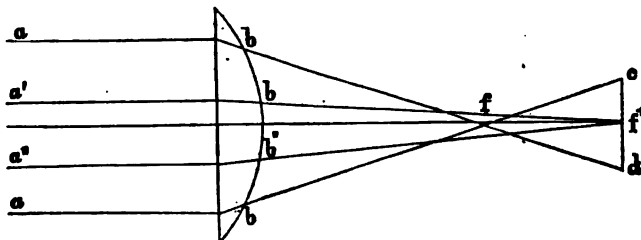


Fig. 9.

b' b'' are passing through near the centre, and are converged to the focus *f'*. Therefore, if a screen were to be held at *c d*, the central rays would be thrown upon it in a state of divergence, or they would be retarded at *f* before they had come to a focus. This would render the image indistinct, or there would be a want of "sharpness" in it. The difference between the focal points of these central and circumferential rays is termed the *spherical aberration*. Therefore, to produce a perfect and distinct image, it is necessary that the curvature of the lens around the centre should be increased, so that the rays which pass through shall be brought to a focus nearer to the lens. And conversely, the curvature of the lens should be diminished nearer the circumference, so that the rays shall be thrown off to a greater distance from the lens. The concavo-convex lens, or meniscus, fulfils these conditions partially. This curvature of this lens is really the segment of an ellipsoid instead of a sphere, and in which the curvature diminishes from the axis to the circumference. It was Descartes who discovered that in lenses, the sections of which are ellipses or hyperbolae, spherical aberration is entirely removed. This is rendered clear in Fig. 10, where if *a l*, *a l'* be part of an ellipse, whose greater axis is to the distance be-

tween its foci $f f$ as the index of refraction is to unity, then parallel rays $r l'$, $r'' l$, incident upon the *elliptical* surface $l' a l$, will be refracted by the single action of that surface into lines which would

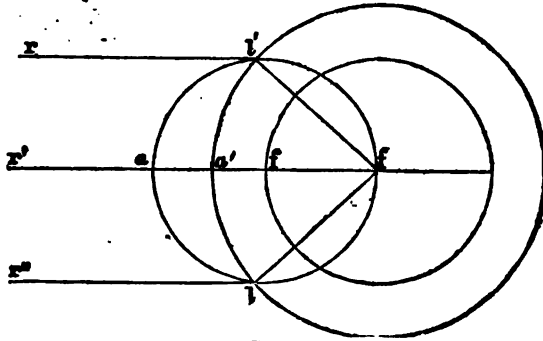


Fig. 10

meet precisely in the farther focus f , if there were no second surface intervening between $l a l'$ and f . But as every useful lens must have two surfaces, we have only to describe a circle $l' a' l$ round f as a centre for the second surface of the lens $l' l$. In this lens the circular surface is perpendicular to the rays refracted at the surface $l' a l$, and therefore they will pass on to f without undergoing any farther refraction at the surface $l' a' l$. A lens, therefore, the convex surface of which is a section of an ellipsoid, and the concave

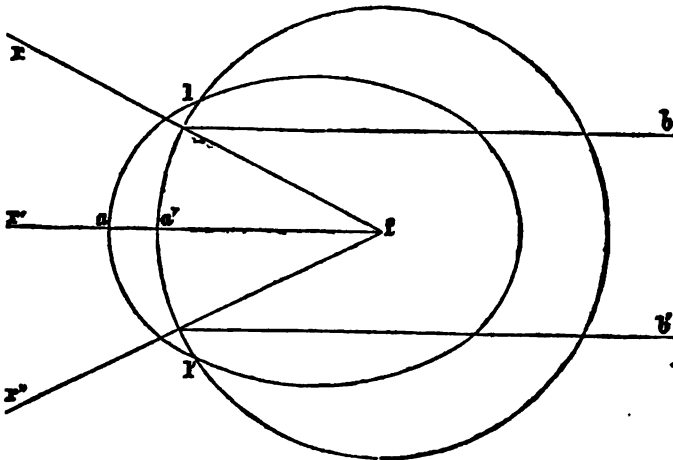


Fig. 11.

surface a section of a sphere whose centre is in the farther focus of the ellipsoid, will be devoid of the properties of spherical aberration, and will refract rays which fall upon its convex surface to the farther focus.

The lens $l\ l'$ in Fig. 11 is a concavo-convex lens, the concave surface of which ($l\ a'\ l'$) is a circle described round the farther focus of the ellipse. If parallel rays ($b\ l, b'\ l'$) impinge upon the concave surface, they will be diverged in the direction of $l\ r, l'\ r''$. If these rays are continued backwards, they will meet in the focus f . This is its virtual focus.

If the surface of a plano-convex lens $l\ a\ l'$ (Fig. 12) forms part of a hyperboloid, which is formed by the revolution of an hyperbola, the greater axis of which is to the distance between the foci as unity is to the index of refraction, then parallel rays $r\ l, r''\ l'$ falling perpendicularly in the plane surface will be refracted without aberration to the farther focus of the hyperboloid.

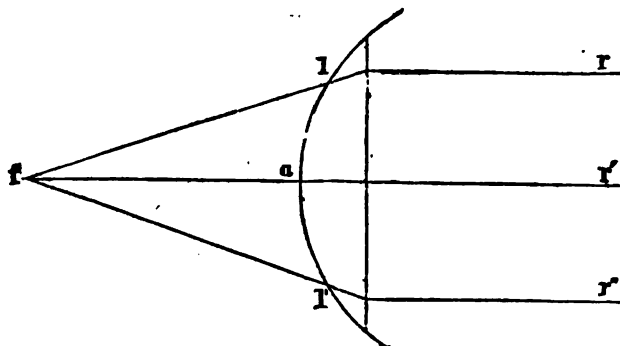


Fig. 12.

The same property belongs to a plano-concave lens having a similar hyperbolic surface, and receiving parallel rays in its plane surface.

It should be borne in mind that in none of these lenses would the object be correctly seen in focus, except at the one point, known as the mathematical or geometrical axis of the lens. (Hogg.)

When the convex side of a plano-convex lens is exposed to parallel rays, they will be brought to a focus at the farther circumference of its own circle, *minus* two-thirds of the thickness of the lens; but if the plane surface is exposed to the rays, then the focus will fall exactly on the farther circumference of its own circle, or on twice the radius of its convex surface.

The combination of lenses recommended by Sir John Herschel is a contrivance to get rid of the spherical aberration. As the aber-

ration of a concave lens is just the opposite of that of a convex one, the aberration of the one can be made to correct that of the other. The combination proposed by Herschel consists of a plano-convex lens, and a meniscus, or concavo-convex lens. The latter is placed with its convex surface in contact with the plane surface of the former. These doublets are fully equal to those of the Coddington lens, if not superior to them, as they afford a large field, and are entirely devoid of spherical aberration.

CHROMATIC ABERRATION.

It will be seen in the solar spectrum that the different-colored rays which form white light are possessed of very unequal refrangibility, so that even the meniscus, which is devoid of spherical aberration, does not bring them all to the same focus. The prism is the best instrument to illustrate this unequal refrangibility of the colored rays, as the solar spectrum is but an illustration of it. This separation of the colored rays is termed *chromatic aberration*, and may be rendered clear by inspecting Fig. 13; *a b* are rays of white

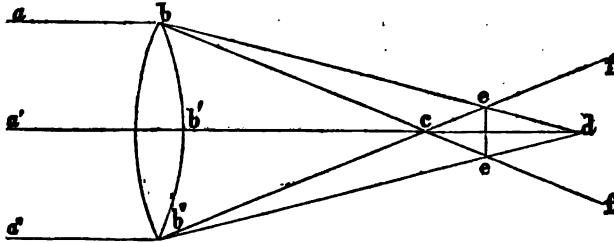


Fig. 13.

light passing through the circumference of the double-convex lens. The violet rays are brought to a focus at *c*, being the most refrangible. The light there diverges in the direction of *ef*; *d* is the focus of the red rays, which are the least refrangible. These rays are crossed at *e e* by the violet rays. The middle point, therefore, of this line is the mean focus, or focus of least chromatic aberration.

To correct this aberration was another practical problem which required years to solve; but it has been effectually done, and that great triumph of the age, the Achromatic Lens, is the result. This was accomplished by resorting to the different dispersive powers of differently constituted glass. The two species of glass used are flint and crown glass—the dispersive power of the former being so much greater than that of the latter, that if the lens *a a* (Fig. 14) be formed of crown glass, whose index of refraction is 1.519, and dispersive power 0.036, and the lens *b b* be formed of flint glass—which

contains a quantity of the oxide of lead, and is consequently much denser—whose index of refraction 1.589, and dispersive power 0.0898, and if the focal length of the convex crown-glass lens is formed so as to be $4\frac{1}{4}$ inches, while the concave flint-glass is $7\frac{3}{4}$ inches, the compound achromatic lens will have a focal length of 10 inches, and will bring rays of light $c c'$ to a focus at d entirely free

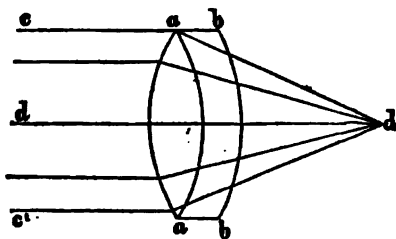


Fig. 14.

of color. These achromatic lenses are now formed with great nicety, and constitute particularly the "objectives" of the compound Achromatic Microscope.

The refractive power of media is generally in a ratio to their density and combustibility. The former is the case with the flint and crown glass, the former refracting with greater power than the latter, as its substance is denser. The refractive powers of oil of cinnamon and of sulphuric acid present a striking illustration of ir-

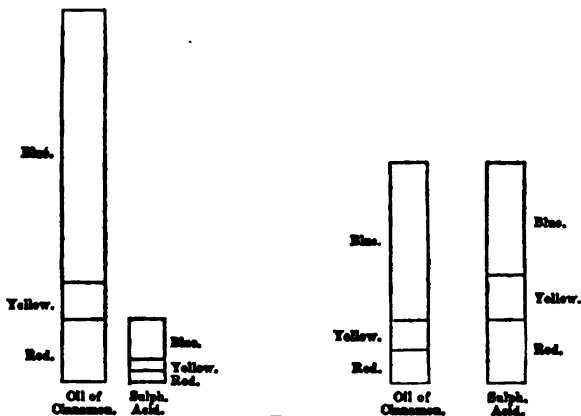


Fig. 15.

rationality of dispersion. Fig. 15 will illustrate this. The longest spectrum is that produced by the oil of cinnamon, while the short one is that produced by the sulphuric acid.

In the case of the oil of cinnamon, the spectrum is extended to an abnormal length, while that produced by the sulphuric acid is just the reverse. If the two spectra are reduced to the same length, and if they be applied to each other face to face, the colored spaces will be recombined into white light. In the case of lenses, as mentioned above, if two kinds of glass are used whose dispersive power is in the proper ratio, this combination of the colored rays into colorless light will be obtained. Thus by a proper regard to the curvature of the lenses, spherical aberration is obviated, while by adopting two qualities of glass, and forming them into lenses of a peculiar construction, chromatic aberration is dispensed with. It would not be in place in a work like this to allude further to the subject of lenses, nor to the interesting and instructive subject of the passage of rays through them. This belongs more properly to the science of Optics, and may be perused by the student in works devoted especially to that subject, or in works devoted to the Microscope.

POLARISATION OF LIGHT.

A ray of light having been observed by Huyghens not to possess the same properties on every side of its circumference, he compared it to a magnet. The minute particles of which the light is composed, are, according to Huyghens, gifted with different poles, which, under certain conditions, arrange themselves in particular positions. From this idea of Huyghens arose the term polarisation. We are, however, indebted to Malus, who, in the year 1808, discovered polarisation by reflection. Since that time a series of splendid phenomena have been elicited by various philosophers, which have given great popularity to this department of science.

Sir David Brewster, in his optics, remarks that the application of the principles of double refraction to the examination of structures is of the highest value. The chemist may perform the most dexterous analysis; the crystallographer may examine crystals by the nicest determination of their form and cleavage; the anatomist or botanist may use the dissecting-knife and microscope with the most exquisite skill; but there are still structures in the mineral, vegetable, and animal kingdoms, which defy all such modes of examination, and which will yield only to the magical analysis of polarised light. A body which is quite transparent to the eye, and which might be judged as monotonous in structure as it is in aspect, will yet exhibit, under polarised light, the most exquisite organisation, and will display the result of new laws of combination which the imagination even could scarcely have conceived.

If a beam of common light is allowed to pass through a small orifice into a darkened room, and if it falls upon, or is reflected from, either a crystallised or uncrystallised body; or if it is trans-

mitted through a thin plate of the same substance, it will be reflected or transmitted in the very same manner, and with the same intensity, whether the surface of the body is held below or above the beam, or on the right side or the left, provided that in all cases it falls upon the surface in the same manner; or what amounts to the same thing, the beam of solar light has the same properties on all its sides; and this is true whether it is white light, as directly emitted from the sun, or from a candle, or any burning or self-luminous body; and all such light is called *common* light. A section of such a beam of light will be a circle like $a b c d$ (Fig. 16),

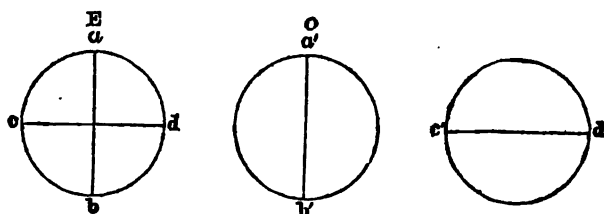


Fig. 16.

and we shall distinguish the section of a beam of common light by a circle with two diameters $a b, c d$, at right angles to each other. If we now allow the same beam of light to fall upon a rhomb of Iceland spar, and examine the two circular beams $O E$, formed by double refraction, we shall find—

1st, That the beams $O E$ have different properties, on different sides, so that each of them differs in this respect from the beam of common light.

2d, That the beam O differs from E in nothing, except that the former has the same properties at the sides $a' b'$ that the latter has at the sides $c' d'$; or in general, that the diameter of the beam, at the extremities of which the beam has similar properties, are at right angles to each other, as $a' b'$ and $c' d'$, for example.

These two beams O and E are therefore said to be *polarised*, or to be beams of *polarised* light, because they have sides or *poles* of different properties, and planes passing through the lines $a b, c d$; or $a' b', c' d'$ are said to be the *planes of polarisation* of each beam, because they have the same property, and one which no other plane passing through the beam possesses. Now, it is a curious fact, that if we cause the two polarised beams $O E$ to be united into one, or if we produce them by a thin plate of Iceland spar, which is not capable of separating them, we obtain a beam which has exactly the same properties as the beam $a b c d$ of common light. Hence we infer that a beam of common light $a b c d$ consists of *two* beams of polarised light, whose planes of polarisation, or whose diameters of similar properties, are at right angles to each other. If O is laid

above E, it will produce a figure like $a b c d$, and we shall therefore represent common light by such a figure. If we were to place O above E, so that the planes of polarisation $a' b'$ and $c' d'$ coincide, then we should have a beam of polarised light twice as luminous as either O or E, and possessing exactly the same properties; for the lines of similar property in the one beam coincide with the lines of similar property in the other. Hence it follows that there are three ways of converting a beam of common light $a b c d$ into a beam or beams of polarised light.

1st, We may separate the beam of common light $a b c d$ into its component parts O and E.

2d, We may turn around the planes of polarisation $a b c d$ till they coincide, or are parallel to each other.

3d, We may absorb, or stop one of the beams, and leave the other, which will consequently be in a state of polarisation.

POLARISATION BY REFLECTION.

It was discovered, as mentioned before, that if a beam of light be allowed to fall upon a plate of glass, as was discovered by Malus in 1808, at an angle of incidence of $56^\circ 45'$, the two beams will be possessed of different properties, as above mentioned, on different sides. If another plate of glass is held over the first, it will be ascertained that the beam reflected from the first glass will pass through it when it is held in some positions, and not in others. If now this glass is turned round without altering its angle with the horizon, the light will be reflected at one quadrant, transmitted in the second, reflected in the third, and transmitted again in the fourth. Or, in other words, the beam of light has acquired the property of sides, one of which is reflected, the other not. The following apparatus (Fig. 17) has been devised for the purpose of illustrating the polarisation of light by reflection. The tube D is a little

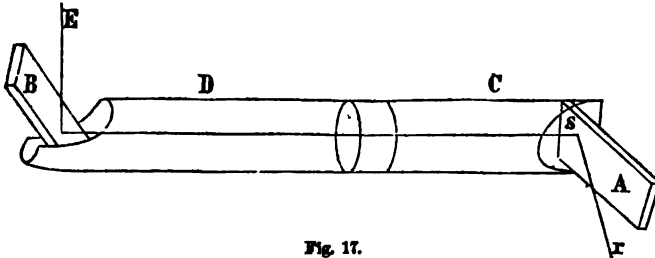


Fig. 17.

larger than the tube C, and fits over it. The tube C has a plate of glass at its end, which turns round on its axis, so that it is capable of forming different angles with the axis of the tube. The tube,

which is larger than C, also has a plate of glass attached to its end in every way similar to that at C. By turning either of these tubes, the two plates may be placed in any position required.

If a beam of light *r s* is allowed to fall upon the plate A at an angle of $56^{\circ} 45'$, and its tube be revolved so as to represent the position in the figure, the beam will be reflected to E. If now the plate be turned around till another quadrant is reached, the light, which was before reflected, will now be found to pass through the plate. If the turning of the tube is continued, when 90° more have been reached, the beam will have entirely ceased to pass through the plate, but will again be totally reflected. These changes take place at every quadrant, the beam being alternately reflected and transmitted.

For the purpose of polarising light, several substances have been employed, as, for instance, the tourmaline, or glass blackened on one side, a bundle of thin glass plates, or a crystal of Iceland spar, calcareous spar, or carbonate of lime. The tourmaline is a crystalline mineral, and is used extensively by opticians for the purpose of polarising light.

The best mineral for the purpose is that which stops the most light when its axis is at right angles to the polariser and yet admits the most when in the same plane. (Woodward.)

POLARISATION BY REFRACTION.

The mineral called Iceland spar, or calcareous spar, which is a carbonate of lime, is generally used for the purpose of illustrating the polarisation of light by refraction. Its composition consists of one equivalent of lime 28, and one equivalent of carbonic acid 22. It is found in various forms, but whether in the crystallised or in mass, it can be split into the shapes represented by Fig. 18. This figure is called a rhomb of Iceland spar. It is a solid, bounded by six equal and similar rhomboidal surfaces, the sides of which are parallel, and the angles *b a c*, *a c d* are $101^{\circ} 55'$ and $78^{\circ} 5'$.

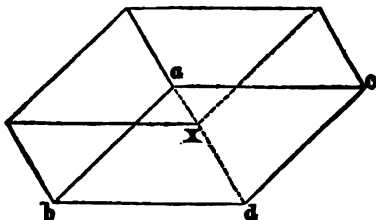


Fig. 18.

The line *a x* is the axis of the crystal or rhomb. It is equally inclined to each of the six faces, at an angle of $45^{\circ} 23'$. This crys-

tal is generally colorless and transparent; and when split, its faces are generally highly polished and even. If this should not be the case, then the faces can be ground and polished, or the same may be effected by new cleavage.

If we look through a crystal of Iceland spar at a dot upon paper, there will be represented two dots. If the paper be now turned around, the dots will appear to revolve likewise twice in the revolution, appearing to fall upon each. This occurs when the paper has been turned one-half round, or when the two dots are turned one-half around from the position they at first occupied. In Fig. 19 the dots appear double, as at *e* and *f*.

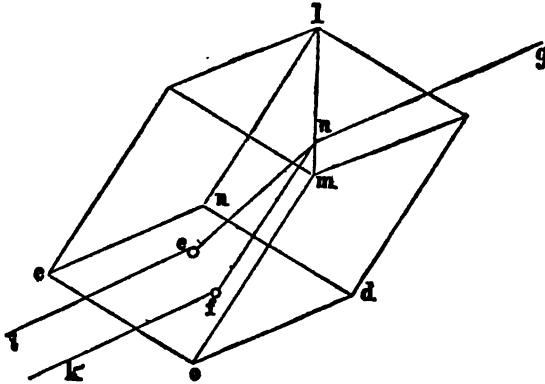


Fig. 19.

If a ray of light *g h* falls upon the crystal, it will become separated into two rays in its passage through the crystal, and which are represented by the letters *h f*, *h e*. Upon arriving at the opposite surface of the crystal, the two rays will pass out at *e f*, in the direction of the lines *i k*, and which are parallel to *g h*. The letters *l m n o* indicate the principal section of the crystal. The line drawn from the solid angle *l* to the angle *o* designates the axis of the crystal, and is the optic axis of the mineral. All beams of light which pass along this axis are undivided, and consequently but one image is formed; but in whatever other direction the beam takes in its passage through the crystal, there are formed two images.

If two crystals are placed upon each other with their principal sections at right angles to each other, the ordinary ray, reflected by the first, will be the extraordinary in the second, and *vice versa*. At the intermediate position of the two crystals there is a subdivision of each ray, and therefore four images are seen. When the crystals are at an angle of 45° from each other, then the images are all seen of equal intensity.

THE PRODUCTION OF COLOR BY POLARISED LIGHT.

The following diagram (Fig. 20) will illustrate the production of color by polarised light. It supposes that light is manifested by the vibrations of an attenuated medium termed the luminiferous. We have in another place given our reasons wherefore we regard the sun's light as a compound consisting of several activities. Perhaps, for the present, the colorific rays may be regarded as vibrations of the luminiferous medium, although this is not proved, and therefore should not be accepted as an ascertained truth.

That the diagram may be rendered as intelligible as its inventor, Mr. Woodward, has done in his able work upon Polarised Light, it would be well to remark that ordinary light is represented by a cross, which indicates that its vibrations are in planes at right angles to each other. When only one set of such vibrations are shown, then the light is regarded as polarised. In Figure 20, *a b c d* represent the rectangular vibrations of common light; *a* is a plate

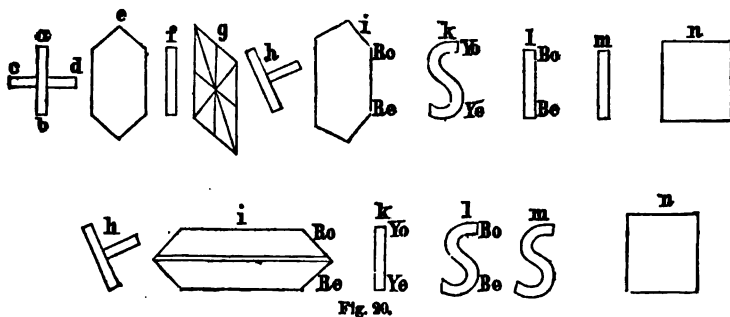


Fig. 20.

of tourmaline, with its axis in a vertical direction. This plate is termed the *polariser*. *f* is a beam of polarised light obtained from *a b c d* by the arrestage of the plane *a d*; *g* is a film of selenite, of such thickness as to produce red or green light; *h*, the polarised beam *f* split into two planes at right angles to each other; *i*, a second or analyser, with its axis in the same direction as that of *e*. By this, all the vibrations that are not inclined at a greater angle than 45° to the axis of the analyser, can be transmitted and again brought together; *k*, the waves *Ro Re* of the red light, meeting in the same state of vibration, and forming a wave of red light of double the intensity; *l m*, the waves *Yo Ye* and *Bo Be* for yellow and blue meeting together, with a difference of an odd number of half undulations, and thus neutralising each other by interference; *n*, the resultant red light.

In the next line of figures may be seen what takes place by turning the analysing tourmaline one quarter of a circle: *h* represents the

polarised beam split into two rays; *i*, the tourmaline turned so that its axis is at right angles to that in the preceding figure; *k*, the waves *Ro Re* of red light destroying each other by interference; *l m*, the waves *Yo Ye* and *Bo Be* for yellow and blue, meeting together in the same state of vibration, and by their coincidences producing waves of double intensity for yellow and blue light; *n*, green light, resulting from the mixture of the yellow and blue light respectively. By substituting Nicol's prisms for the two plates of tourmaline, and by the addition of the object-glass and eye-piece, the diagram would then represent the passage of polarised light through the microscope.

Selenite is used in the polarisation of light. The particular tint of color is determined by the thickness of the selenite. If the same mineral is of different thicknesses, then different colors are produced. These facts admit of the most beautiful results when used properly under the microscope.

Selenite is the natural hydrated sulphate of lime crystallised. It frequently occurs in very large crystals, which present the form of an oblique rectangular prism, with ten rhomboidal faces. Two of these faces are larger than the others, and admit of being split into thin laminæ parallel to them; these laminæ, having a thickness of one-twentieth to one-sixtieth of an inch. In the two rectangular directions, they allow perpendicular rays of polarised light to penetrate them unchanged. These directions are termed the *neutral axis*. In the two other directions, which form angles of 45° with the neutral axis, these laminæ have the property of double refraction. These latter directions are termed the *depolarising, doubly refracting axis*.

There is a salt of quinine which appears to possess great polarising properties. It is prepared by dissolving disulphate of quinine in concentrated acetic acid. The solution, after being warmed, has dropped into it carefully, and by small quantities at a time, a spiritous solution of iodine. Brilliant plates of the new salt will be formed, after having set the solution aside for a while. The crystals of this salt, by reflected light, are of a brilliant emerald green color, not unlike the crystals of meurexide, and presenting the metallic lustre characteristic of the elytræ of many beetles. By transmitted light they present but little color, and that of a slight olive-green. If two crystals lay across each other at right angles, the place of intersection is marked by perfect blackness, although the crystals may not be the five-hundredth of an inch in thickness. Light in the slightest degree polarised—as even by the reflection from a cloud, or by the blue sky, or from the glass surface of the mirror of a microscope placed at the polarising angle—these prisms immediately assume complementary colors, one appearing green and the other red, while the place at which they cross is of a deep brown color. This salt possesses the properties of tourmaline in an exalted degree, as well as

of a plate of selenite, so that it possesses the properties of polarising a ray of light, and then of depolarising it. These crystals have been lately formed by Dr. Herapath, their discoverer; large enough to answer the purpose of an analyser to the microscope. This is a great desideratum, as by these crystals all the phenomena of polarised light can be effected without the use of the tourmaline or Nichol's prism. Besides, the brilliancy of the colors is much more heightened by the use of these crystals, than if either the tourmaline or the Nichol's prism were used. As an analyser above the eye-piece of the microscope, it offers advantages over the Nichol's prism in the same position, as it gives a perfectly uniform tint of color over a much more extensive field than can be had with the prism.

The discovery of the wonderful polarising properties of the double salt of quinine and iodine, has led to the adoption of polarised light for the detection of the salts of the alcaloids, &c., in the urine of patients. By this means Dr. Herapath has succeeded in detecting the one-millionth part of a grain of quinine in organic fluids.

This application of polarised light is another evidence of the good results which accrue from discoveries which at first appear to present no real value to man. It is desirable to the medical man, that he should be enabled to trace the progress of his medicine through the system—if it should pass undecomposed through it; and if not, that he should be aware of the fact. The test fluid for the purpose is composed of a mixture of three drachms of pure acetic acid, with one fluid drachm of rectified spirits of wine, to which is added six drops of diluted sulphuric acid. If one drop of this test fluid is placed on a slide, and the minutest quantity of alcaloid is added, solution in a brief time will take place. Then upon the tip of a very fine glass rod, let an extremely minute drop of the alcoholic solution of iodine be added. The first effect is the production of the yellow or cinnamon-colored compound of iodine and quinine, which forms a small circular spot. The alcohol separates in little drops, which, by a sort of repulsive movement, drive the fluid away. After a time, the acid liquid again flows over the spot, and the polarising crystals of sulphate of iodo-quinine are slowly produced in beautiful rosettes. This succeeds best without the aid of heat. To render these crystals evident, it is only necessary to place the glass slide under the microscope, with the selenite stage and single tourmaline, or Nichol's prism, beneath it. Instantly the crystals assume the two complementary colors of the stage: red and green, supposing that the pink stage is employed; or blue and yellow, provided the blue selenite is made use of. All those crystals at right angles to the plane of the tourmaline, produce that tint which an analysing plate of tourmaline would produce when at right angles to the polarising plate; whilst those at 90° to these, educe the complementary tint, as the analysing plate would also have done if revolved through an arc of 90° .

To test for quinidine, it is merely necessary to allow the drop of acid solution to evaporate to dryness upon the slide, and to examine the crystalline mass by two tourmalines, crossing at right angles, and without the stage. Immediately little circular discs of white, with a well-defined black cross very vividly shown, start into existence, should quinidine be present even in very minute traces. If we employ the selenite stage in the examination of this object, we obtain one of the most gorgeous appearances in the whole domain of the polarising microscope. The black cross at once disappears, and is replaced by one which consists of two colors, being divided into a cross having a red and green fringe, whilst the four intermediate sectors are of a gorgeous orange-yellow. These appearances alter upon the revolution of the analysing plate of tourmaline. When the blue stage is employed, the cross will assume a blue or yellow tint, according to the position of the analysing plate. (Herapath.)

The application of polarised light to the illumination of very minute structures, has not yet been fully carried out. But still there is no test of differences in density between any two or more parts of the same substance that can at all approach to it in delicacy. All structures, therefore, belonging either to the animal, vegetable, or mineral kingdom, in which the power of unequal or double refraction is suspected to be present, are those that should especially be investigated by polarised light. Some of the most delicate of the elementary tissues of animals, such as the tubes of nerves, the ultimate fibrillæ of muscles, &c., are amongst the most striking objects that may be studied with advantage under this method of illumination. Every structure that the microscopist is investigating, should be examined by this light, as well as by that either transmitted or reflected. Objects mounted in Canada balsam, that are far too delicate to exhibit any structure under transmitted, will often be seen under polarised light. Its uses therefore are manifold. (Queckett.)

EPIPOLISED AND FLUORESCENT LIGHT.

Most persons have noticed the difference of color exhibited by a solution of sulphate of quinine, acidulated with sulphuric acid, when examined by transmitted and by reflected light. In the former it presents a transparent colorless solution, while in the latter it assumes the appearance of a beautiful blue color. A variety of the mineral called fluor spar, or the fluato of lime, presents the same phenomenon. A glass colored yellow by the oxide of uranium does the same, except that the reflected light is green instead of blue, as is the case with the quinine solution. Sir John Herschel has shown that these blue or green hues proceed from a thin stratum of the fluid at the surface, and that the rays of light which have passed through this stratum, lose their property of producing the same effect. These rays Herschel has termed the *Epipolic* or *Epipolised*

light. Similar phenomena have been produced in a solution of chlorophyll, by passing a beam of solar light, concentrated by a lens, into the solution. When the quinine solution was examined in this way, it was ascertained that the light was not only dispersed at the surface, but likewise at some distance within the body of the fluid. (Brewster.)

If a ray of light, concentrated by a lens, is thrown into a solution of quinine, or into a piece of uranium glass, a cone of rays of a blue color for the quinine, or of a green color for the uranium glass, will be observed to penetrate the medium. These rays are entirely different from the rays of the ordinary spectrum. If a pencil of light is refracted by a prism, and these refracted rays, being first received on a good achromatic lens, the spectrum is thrown upon others of the above media, or any of those formerly mentioned, and we look through the sides in upon the image, we shall see all the least refrangible rays, rendered evident by motes in the fluid passing freely through; and if the spectrum is received on a screen, but little loss of light or color will be perceived. From a certain point near the least refrangible violet rays—but this varies somewhat with the medium employed—small cones of light, of the peculiar colors of the light from the surface of the quinine solution, or the canary yellow (uranium) glass, will be seen passing into the solution or glass to various depths, and these will be found to extend with varying degrees of intensity beyond the violet and lavender rays. By this method it is shown that rays of high refrangibility, existing over the space usually included in the term, "Ritter's dark rays," are rendered visible. Hence it has been inferred that, since the most active chemical rays exist within the limits comprehended by these rays, that they are rendered visible. (Stokes.) This peculiar optical phenomenon has been designated by Professor Stokes as Fluorescence. The results of his lengthy series of investigations may be comprehended in the following.

In the phenomena of true internal dispersion, the refrangibility of light is changed,—incident light of definite refrangibility giving rise to dispersed light of various refrangibilities.

The refrangibility of the incident light is a superior limit to that of the component parts of the dispersed light.

The color of light is in general changed by internal dispersion, the new color always corresponding to the new refrangibility. It is a matter of perfect indifference whether the incident rays belong to the visible or the invisible part of the spectrum.

The nature and intensity of light dispersed by a solution, appear to be strictly independent of the state of polarisation of the incident rays. Moreover, whether the incident rays be polarised or unpolarised, the dispersed light offers no traces of polarisation. It seems to emanate equally in all directions, as if the fluid were self-luminous.

The phenomena of a change of refrangibility prove to be extremely common, especially in the case of organic substances, such as those ordinarily met with, in which it is almost always manifested to a greater or less degree.

It affords peculiar facilities for the study of the invisible rays of the spectrum, more refrangible than the violet, and of the absorbing action of media with respect to them.

It furnishes a new chemical test of a remarkably searching character, which seems likely to prove of great value in the separation of organic compounds. The test is specially remarkable for this, that it leads to the independent recognition of one or more sensitive substances in a mixture of various compounds, and shows to a great extent, before such substances have been isolated, in what menstrua they are soluble, and with what agents they enter into combination.

It therefore appears that the solar light is composed of at least three luminous or colorific rays; of the Actinic, or chemical rays; of the Thermic, or heating rays; and of the Fluorescent and Epipolised rays. It is maintained by some, that besides the three colorific rays, blue, yellow, and red, there are the lavender and the extreme red. There are other rays, again, which appear to retard chemical action. Whether they are rays *per se*, possessed of a peculiar nature; or whether their retarding influence, and that produced in the maturation of fruits and flowers, and in the changing of the color and condition of the chlorophyll of foliage in the autumn, is due to that of the other rays, remains yet to be discovered.

MAGNETISING PROPERTIES OF LIGHT.

For the last twenty years the question has been discussed, whether either of the solar rays possesses the power to develop magnetism in iron or steel. Dr. Morichini first announced that the violet ray imparts to iron the property of polarity. The experiments of Mrs. Somerville were soon afterwards published, which went far to establish the assertion of Dr. Morichini. Immediately upon reading these experiments of Mrs. Somerville, we were led to suspect that she had deceived herself. Our reasons for this conviction are these. It is well known to electricians, that if a piece of steel be laid for a short time with its axis in the direction of the magnetic meridian, that it will soon become magnetic. This led us to suspect that perhaps Mrs. Somerville, and those who had preceded her, and likewise those who had subsequently confirmed her experiments, had laid the needles they magnetised directly along the magnetic meridian, or north and south. With a view of testing the truth of these experiments, we submitted a number of needles, previously determining that they were not possessed of magnetism, to the action of the violet ray. Some of these needles we placed directly north and south, and others east and west. After several hours had elapsed we ex-

amined them, when we perceived that those which had laid north and south had acquired a feeble polarity, while those which had reposed east and west, were entirely free from magnetism. We ascertained that no length of exposure of the east and west needles to the violet ray, or to the direct sunshine, would develop magnetism in them; while it only required a few hours in the shade, and not exposed to any of the isolated rays, but only to diffused daylight, to develop magnetism in the north and south needles. The development of magnetism by the action of light, has therefore arisen from error in deduction. The magnetism of the needles was only that secondary polarity derived from the inductive influence of the earth, and was not developed through the action of either violet or white light.

MAGNETISATION OF LIGHT.

An elaborate series of experiments, made by Professor Faraday, would appear to prove that light is susceptible of being strongly affected by the magnet, and that therefore it possesses polarity. But it appears that in all of Dr. Faraday's investigations, some transparent medium was always required in order to obtain the successful polarisation of light, and that the amount or strength of polarisation was in a ratio to the density of the medium. From this it would appear that the light was not polarised. The molecular arrangement of the medium through which the ray was passed was altered, so that there was a change in its refracting power, which of course changed the condition to the light as it passed through it.

The experiments of Dr. Faraday do not appear to have revealed any new properties in the solar beam, at least so far as its susceptibility to magnetism is concerned.

PHOSPHORESCENCE.

Phosphorescence is light without heat. So far as our most delicate instruments are concerned, no heat has been detected in phosphoric light, not even by Melloni's Thermo-Multiplier, the delicacy of which is such that the vital heat of insects are cognisable by it.

1. *Phosphorescence of Living Animals.*—The phosphoric light of living animals appears to proceed from a fluid given out by them, and which probably contains phosphorus, or some element which combines at ordinary temperatures with the oxygen of the air, or of the water. The elimination of this fluid appears to depend upon the volition of the animal. The vital process may be the mediate cause of the phosphorescence, and not the immediate, as is maintained by several philosophers. It is evident that the excitation of the animal, through immersion in oxygen gas, is the cause of the increased glow of its light; as its diminished intensity in mediums which have

a tendency to depress the vital powers, proceed from the opposite cause.

Those animals which emit a phosphoric glow during life, belong to the lower classes of existence, such as the worms and insects,—also several species of infusoria and medusæ.

2. *Phosphorescence of Living Plants.*—There are several species of flowers which give out flashes of phosphoric light on fine summer evenings, just after sunset. There are ten varieties of these plants enumerated, which emit light of nights.

Many plants emit a steady glow. This proceeds probably from the formation of some substance which oxidises slowly. This substance, Gmelin thinks, does not contain phosphorus, but some compound containing carbon and hydrogen. The foliage of the *Phytolacca decandra* emits a bluish green light steadily from early in the evening until midnight. There are seven plants enumerated which give out a steady light, besides many conservæ.

3. *Phosphorescence of Putrefying Animals.*—In the presence of moisture and a certain temperature, and when oxygen is present, a peculiar decomposition takes place in dead animal matter. This appears to be the incipient process of putrefaction, and gives rise to a glutinous substance, the constituents of which are susceptible of oxidising with the elimination of a pale feeble light, and no heat. Human bodies are occasionally phosphorescent. We have witnessed one instance which exhibited itself vividly in taking up a body which had laid for several days. A pillar of silvery phosphorescent light arose for eight or ten feet above the grave, and remained there for several minutes. This phosphorescent matter appears to be contagious by contact, as one body, not before luminous, has been known to become so by contact with another which was. The luminous matter generated, appears to be of an oily nature, and can be removed by the finger, where it continues to emit light. It shines with great vividness under the microscope, with a vacillating motion, as if it were the receptacle of innumerable infusoria, which however is not the case. This luminous substance continues to shine in oxygen, carbonic acid, phosphoretted hydrogen, carbonic oxide, and nitrogen. It loses its luminous properties in a vacuum, but recovers it upon the admission of air. The luminousness is extinguished in sulphuretted hydrogen and chlorine gas.

Phosphorescence is readily exhibited by sea-fishes. Sixteen varieties are enumerated which give out a phosphorescent light. Many fishes after death give out a luminousness if in contact with oxygen. This proceeds from a process of decomposition, and is attended with no rise of temperature. This phosphorescence disappears when fetid putrefaction has fairly set in.

4. *Phosphorescence of Decaying Plants.*—In the presence of air and moisture, plants undergo phosphorescence, but a small quantity of oxygen must be present. The luminous compound generated by

the decomposition of wood, is a slowly combustible compound formed of carbon, hydrogen, and oxygen, from the original proximate constituents of the plant. More than a dozen species of wood are enumerated which become phosphorescent. The phosphorescence of wood is attended with the abstraction of oxygen from the air, and the production of carbonic acid gas. (Dessaignes.)

PHOSPHORESCENCE BY INSOLATION, OR IRRADIATION.

There are a number of bodies which possess the property of giving out light after having been exposed to the solar rays. The cause of this is perhaps that the phosphori absorb light pure and unaltered, and then give it out again devoid of its heat. This would appear to give strength to the corpuscular theory of light. The cause of this phenomenon is probably that the bodies, by being exposed to light, absorb a portion of it unaltered into their substance by adhesion, and subsequently give it out in a dark place—because there the effort of the light to diffuse itself uniformly through the space devoid of light, overcomes its adhesion to the ponderable matter. (Gmelin.)

1. *Bonnonian Phosphorus*.—This is formed of the sulphate of baryta, which must be perfectly free from iron and other metals.

2. *Strontian Phosphorus*.—This phosphorus is prepared by heating it in a crucible, as is the process with the above. Its power of absorbing light may be greatly increased by adding from three to four per cent. of the powdered cælestin.

3. *Conton's Phosphorus*.—This is really the sulphide of calcium, and is prepared by adding calcined oyster-shells to sulphur in a crucible, and submitting to strong heat.

4. *Osann's Phosphori*.—One of these phosphori is prepared by heating calcined oyster-shells with finely powdered sulphide of antimony in a crucible.

Another is made by the process mentioned above, only using Realgar (the sulphide of arsenic) in the place of the sulphide of antimony.

5. *Wach's Phosphori*.—Is composed of burnt oyster-shells and the tersulphide of arsenic. Another contains the oxide of zinc. Another with the oxide of cadmium. Another with the peroxide of zinc. Good phosphori are made by igniting the hyposulphite or sulphate of baryta, strontia, or lime, with three or four per cent. of magnesia.

6. *Homburg's Phosphorus* is made by melting one part of sal ammoniac with two parts of slaked lime. It is a chloride of calcium.

7. *Baldwin's Phosphorus*.—This is the nitrate of lime, fused until the nitric acid begins to decompose.

The above phosphori possess the property, when they are exposed

to the solar rays, of absorbing light in greater or less quantity, and of giving it out again when brought into the dark. Several of them become luminous by exposure to strong artificial light.

The diamond is even rendered luminous by moonlight. This is also the case with Conton's phosphorus. This phosphorus becomes luminous after an exposure of two seconds to daylight, even after being immersed in water.

A number of investigations have been made, with the view of ascertaining which of the solar rays produce phosphorescence. The violet rays, or the actinic, which are located within the violet light, appear to be the exciting cause of phosphorescence. This is proved from the fact that the power of producing luminousness increases with the refrangibility of the rays. The red rays, or those least refrangible, do not induce phosphorescence. In fact, phosphorus, which has been rendered luminous by the violet or white light, soon loses its brightness by being placed in the red rays. Phosphorus placed in the violet rays, has light induced within it, quite as vividly and speedily as can be done by white light condensed through a lens. From this we arrive at the conclusion that it is the actinic or chemical rays alone which induce phosphorescence. Some of the above phosphori lose their properties in time, but regain them again after having an electric shock passed through them. In fact, several of them become luminous when the electric spark is passed near them—equally as much so as if they were exposed to sunlight. But it is the light of the spark which perhaps induces the phosphorescence.

When these phosphori have lost their power to shine, they acquire it again by being heated in the dark. It seems therefore that these bodies, at the ordinary temperature, contain a certain quantity of light so intimately combined with them, that it cannot diffuse itself through a dark space by virtue of its own elasticity, but that the capacity of bodies to fix light diminishes as their temperature rises. (Gmelin.)

Nearly all the earthy minerals become luminous when heated. Also several of the salts, as sulphate of quinine and cinchonine. Several of the resins, when submitted to a heat at which they begin to char, become phosphorescent. This, perhaps, ensues from a process of combustion.

PHOSPHORESCENCE OF CRYSTALLISATION.

Many salts in crystallising from their solutions, emit sparkling light. Benzoin, in passing from its vaporous condition to that of crystallisation, gives out a bright sparkling light. This phenomenon, perhaps, depends upon the passage of the substance from the amorphous to the crystalline condition. Sulphate of potash when crystallising, gives out sparkles, and this continues until the salt is

entirely crystallised. One part of common salt, and two parts of sulphate of potash, emit sparks while crystallising. These crystals become phosphorescent when rubbed. Sulphate of potash, cream of tartar, and common salt, become highly luminous while crystallising. These crystals shine for several days after. Sulphate of magnesia deprive these crystals of their luminousness. The crystals separated from a solution of sulphate of cobalt and potash, give sparks after they are taken from the solution.

From the instances given above, and hundreds more might be given, it appears that the sulphate of potash possesses the property in the highest degree, of emitting light while passing from its solution to a crystalline state. If, however, other salts are mixed or combined with it, the light appears to increase. The emission of light in the instances above, generally takes place with the development of heat. Therefore, many bodies in passing from the amorphous to the crystalline state, develop light solely; while others, such as grape-sugar, develop heat without the emission of light.

ARTIFICIAL LIGHT.

The most vivid artificial light that we are capable of producing, is that of carbon, ignited by the voltaic current. This light is not the result of combustion, although much of the carbon is converted into carbonic acid during the ignition. In a vacuum, the ignition of the carbon takes place with equal facility and vividness, the carbonaceous particles passing through the illuminated area from the anode to the cathode, upon which it is deposited, the concavity of the anode corresponding to the convexity of the cathode. But the writer of this article, in the year 1845, devised another method of producing the voltaic light. It was, instead of attempting to give stability to the disruptive discharge, to pass the current through a small cylinder of carbon. By means of electro-magnets, the length of the cylinder was regulated by the quantity of the current which passed, so that the carbon was almost at the point of fusion all the time, and therefore in its condition of most intense vividness. This cylinder was inclosed in a vacuum, so that the oxygen of the air could not act upon it. This light has since been patented by others in Europe, but is essentially the same, only slight and immaterial variations of the apparatus, and none in the principle, having been made.

Next to the electrical light, the calcium or oxy-hydrogen light, is the most vivid. It was discovered by Dr. Hare, of Philadelphia, soon after his great discovery of the oxy-hydrogen blowpipe. This light is produced by ejecting from a small orifice two streams of gas, one of oxygen, the other of hydrogen. These gases, when passed out of the orifice in the proportion of one volume of oxygen to two volumes of hydrogen, and thrown upon a cylinder of

quick-lime, having previously lighted them, soon bring the lime up to an intense heat. This incandescence, together with the peculiar luminosity which lime gives out when heated, irrespective of its temperature, produces a bright white light, which can be seen a great distance at sea. The light produced by the voltaic battery on carbon, and that produced by oxy-hydrogen gas on lime, is possessed of the properties attributed to white light. It is susceptible of polarisation, of being separated into the colorific, thermic, and actinic rays, and produces on sensitive paper the same effect as the solar light, only not in such a marked degree. This is generally the effect of all artificial light, except that which emits too many of the yellow rays, which retard the action of the actinic ones. The subject of Artificial Illumination belongs to another department of the science.

THE CHEMICAL PROPERTIES OF LIGHT; OR ACTINO-CHEMISTRY.

It has been stated that there are two theories respecting light. One supposed that the manifestations of light proceed from the oscillations or vibrations of an attenuated ether, or all-pervading principle. This theory supposes that the length of these waves determine the color, and that the shorter the wave, the more there is manifested a tendency to those colors which are most refrangible, as the blues and violets. It supposes that a prism only serves to bend these vibrations out of their rectilinear path. Heat is supposed to be the result of these vibrations, but in waves pulsating to a slower time than light, as the refraction is less. Chemical action is imagined to be the result of these vibrations, but infinitely more rapid than either those of heat or light. These, it should be remembered, are mere hypotheses, which account for some of the phenomena pertaining to light, but not all. The hypothesis of the undulations, or waves, in an attenuated ether, may perhaps, for the present, answer for the luminous rays, but it will not stand the test in regard to those more refrangible ones which produce chemical action.

Suppose we form two spectra upon a wall by means of two prisms. Each of these spectra produces a chemical effect upon chloride of silver, from the edge of the green ray to beyond the violet or lavender gray. Now throw the inactive yellow ray of one of these spectra upon the active violet ray of the other. By this means chemical action is entirely retarded. "This may be due to interference," says Professor Hunt, "but I must confess I cannot understand upon what principle the action of rays undulating 535 millions of millions of times in a second, and producing light, can interfere with rays vibrating 4727 millions of millions of times in the same period, producing, as experiment proves, chemical change. To support the view, that light regarded as an undulation, produces chemical change, since the chemical cause must reside in, must be, the particular ray, and nothing else, it is necessary to prove, that when

we obliterate a colored ray of light, all chemical action should cease over the space which belongs to such especial ray; and also that when the luminous colored ray is not obstructed, its chemical power should still exist undiminished."

The blue rays, which, with the still more refrangible violet ones, are known to exert the most energetic chemical effect, may be entirely obliterated without in the least destroying or retarding their characteristic action. In other cases the blue ray may be made to appear bright and intense, and still produce no chemical action whatever.

It is true that many of the phenomena pertaining to the luminous rays, may be accounted for upon the supposition that they are the vibrations of an attenuated or luminiferous ether; but when we come to take cognisance of the rays which produce chemical action, we find that this theory—this regarding of light as really a non-entity—will not answer the purpose of explanation. It is more in consonance with true science, as developed at the present day by chemistry, to regard light as an absolute entity—an actual material body, which, like all of its material co-ordinates, is susceptible of those changes of condition which all material particles are subject to. In the action produced by the actinic rays, there is undoubtedly something—an actual force—absorbed; and which, forming a true combination with the material particles associated with it, produce those wonderful changes which greet the eye of the actino-chemist daily. With the majority of the chemists of the present day, we are therefore inclined to regard light as actual corpuscles, as Newton did, and to associate the phenomena it produces in matter as the result of its absorption and subsequent combination with the ultimate molecules of matter. "After many years of close experimental examination," writes Professor Hunt, "and an equally long and careful study of the hypotheses applied in explanation of the phenomena of light in the first place, and subsequently to the chemical phenomena associated with light, I cannot bring my mind to adopt the view, which refers the photographic phenomena to the agent producing the luminous and colorific phenomena of the solar rays."

A beam of light may be regarded as a bundle of rays, consisting of the *thermic* or *heat* rays, the *luminous* or *colorific* rays, and the *actinic* or *chemical* rays. Suppose that a beam of solar light is allowed to pass through a small orifice into a darkened room, and as it issues through it, that it be passed through a prism. Upon a screen held at the proper distance from the prism, there will be what is termed the *solar* or *prismatic spectrum*.

Figure 21 will illustrate what is termed the prismatic spectrum. It is an elongated image of colored light, and presents a familiar example of the analysis or separation of the different rays of the sun-beam as first effected by Newton. The least refrangible of the rays are the thermic or heat ones. They are generally found most in-

tense just below the red rays. Then the *red* rays follow in the order of refrangibility. Then the *orange*, which are a blending of the red and the yellow above them. The *yellow* rays follow the *orange* ones of Newton; and above them the *green*, or a blending of

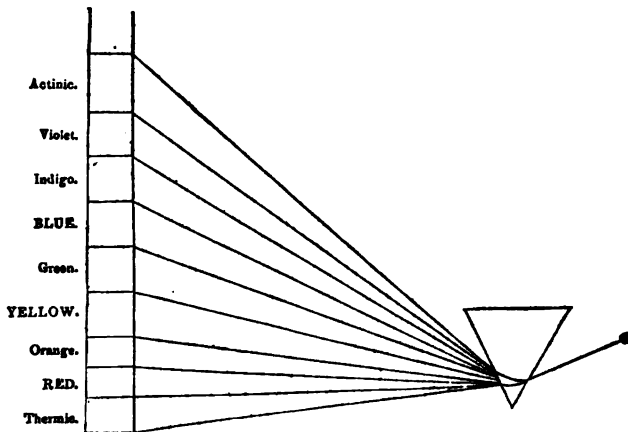


Fig. 21.

the yellow and the *blue*, which are just above the green. The *indigo* and *violet* of Newton are the most refrangible of the color rays. They are, doubtless, modifications of the blue rays, being perhaps effected by the invisible actinic rays still further refracted. These rays, however, by the aid of an acid solution of the sulphate of quinine, are said to be rendered visible. It is, however, doubtful whether these actinic rays are rendered visible, but rather that the light is a still further prolongation of the blue rays, changed in their appearance, as the violet are changed from the blue. It is contended by Sir David Brewster, that there are really but three colorific or luminous rays, viz., the *blue*, *yellow*, and *red*, and that the other colors are but an overlapping and blending of these three colors. For instance, the orange is the blending of the red and the yellow, while the green is that of the yellow and the blue, &c.

By the use of the proper media, these rays, and the thermic and actinic ones, can be separated from each other. If, for instance, we take glass, colored by the oxide of copper, and washed on one side with a solution of alum, we will have a free passage of the luminous rays, while nearly all of the heat-rays will be retarded. If, on the contrary, we use a plate of black mica, nearly all of the light-rays will be obstructed, while those pertaining to heat will have a free passage.

The various rays act quite differently upon sensitive paper. If a

piece of this paper be placed beneath the prismatic spectrum, it will be observed that for some distance below the visible red ray, the paper will remain perfectly white, while even the red ray itself scarcely colors the paper. The orange, or rather the yellow—in which reside the maximum of illuminating power—does not affect the paper, while the green affects it but faintly. It is in the blue ray that we notice the first decided effect upon the paper; and this action continues to manifest itself still more strongly as we continue towards the violet, until beyond it the maximum effect is produced.

From this we learn that the photographic effect does not depend upon the *light*, in its general acceptation of the term, but that it depends upon those more refrangible rays which are refracted beyond the luminous ones, and which are unperceivable. It is highly probable that the *lavender gray* rays of Herschel, and those discovered by Stokes, are merely the diffused light from the luminous ones; for as the actinic rays do not appear to pertain at all to vision, but are solely directed to energies quite distinct from it, we should not suppose that they are gifted with the least luminous quality whatsoever.

The different colorific rays are said by some writers to possess qualities of a specific nature. As, for instance, those rays particularly relating to light and heat, exert no effect whatever upon the sensitive paper. In fact, they appear to *protect* it from chemical action. If we pass the sun's rays through yellow glass, stained by silver, we entirely retard or absorb the chemical agency, while the luminous rays pass through without the least retardation. If, on the contrary, we use dark blue glass, colored with cobalt, it almost entirely obstructs the luminous rays, but does not in the least retard the actinic ones.

It is not philosophical to speak, therefore, of the yellow and red rays (which possess the maximum, of which are the true luminous and heating rays) as being possessed of "retarding rays," as one author has, but simply to regard their retarding effect as a negation. We might as well speak of cold being a positive quality instead of a negative one, as to speak of "retarding rays" in yellow and red light.

By using the yellow glass we are taught that the photographic energy of light does not reside in the luminous rays. By making use of deep red glass, we are taught that this principle is not located in the heat rays; while the blue glass, which is opaque to light and heat, possesses the quality of admitting nearly all of the actinic or chemical rays. These *actinic* rays—which word only signifies "*ray power*"—are then separate and distinct ones, as equally so as are the luminous and heat rays. This fact was the source of great trouble to the earlier photographers, who travelled far south in the expectation that, as they progressed in the regions of more intense light,

they would obtain photographic effects in a ratio to the luminousness of the climate. But in this they were deceived, for as they approached the brilliant tropics, they were surprised at not obtaining pictures in harmony with the brightness of the atmosphere. As it is not the *luminous*, but the colorless *chemical* rays, which produce the photographic effect they sought; and as the sombre climate of England contains more of these rays, but less of the luminous ones than that of the tropics, these persons obtained the best pictures at home.

Instead, therefore, of the solar light being a homogeneous fluid, or substance, poured out from the surface or atmosphere of the sun, we must now regard it as of a composite nature, composed of several distinct rays, each of which have their specific tasks allotted to them. This, perhaps, will be best comprehended in taking cognisance of light in its relations to vegetation.

THE INFLUENCE OF SOLAR LIGHT ON THE GROWTH OF PLANTS.

The experiments of Professor Hunt are quite conclusive to us, even if we had not thoroughly verified them by our own, that seeds do not germinate under the influence of either of the luminous rays, but that they require the stimulus of the actinic ones. In fact, our experiments have gone to establish the fact, that yellow and red light retard, or actually prevent germination. Seeds which were placed under a deep blue light, that scarcely admitted the luminous rays, began to manifest germination in less than a day; while seeds which were placed in the dark did not exhibit symptoms of germination until the expiration of two days. This stimulating effect of the actinic rays extends for some distance into the soil—much deeper than the same influence, as it exists in the solar radiations. The influence which either causes, or awakens, the germinating energy in seeds, resides more powerfully in blue light than in the white light of the sun, for the luminous rays really appear to interfere with the germination of the seed, instead of accelerating it.

The chemical changes which ensue beneath the influence of this wonderful actinic energy are comprehended by the chemist. The seed, which is charged richly with carbon, is so acted upon, that its starch is converted into gum and sugar by the absorption, or conversion of one and four equivalents of water into its own substance—starch ($C_{12}H_{10}O_{10}$),—gum ($C_{12}H_{11}O_{11}$), and sugar ($C_{12}H_{14}O_{14}$). In this case beneath the actinic influence we have a chemical change analogous to the blackening of nitrate of silver associated with organic matter. In the case of the seed, a large quantity of oxygen is absorbed, while carbonic acid is eliminated. In the case of the silver salt, there would not be a change were organic matter not to be present; but if it be there, then a combination with the carbon and oxygen takes place, while simultane-

ously the organic molecules appropriate the oxygen of the oxide of silver to their own use. These changes depend solely upon the action of the actinic rays, and wholly independent of the action of the luminous rays. But after the cotyledons are fully developed, and the plumula has made its appearance above the soil, then new energies are called for in order to insure the vigorous and healthy growth of the plant. This can be proved by continuing the influence of the blue rays after the plant shall have pierced the surface of the earth. It is true that the plant will continue to grow with great rapidity, but the growth is unhealthy, for the stalk will continue succulent and will contain no ligneous matter. The yellow and red rays appear to impart to the plant the power of appropriating the elements in the formation of woody fibre, while the actinic power influences the plant to absorb water. Plants, therefore, which grow in the shade are more watery and less firm than those grown in the sunshine. The actinic principle it appears acts principally in developing the plant until it is ready to put out into leaf. After that, the influence of the colorific rays is required, else the plant will progress no further than the formation of the plumule or first leaf-bud. No ligneous matter is formed, but the soft watery stem continues to grow to an enormous length. This great growth of the stem appears to proceed from the strong excitement or stimulus of the actinic rays, while it requires the aid of the luminous principle to insure woody fibre. As the plant will not mature into leaf, there is no carbonic acid decomposed, and consequently no carbon fixed to supply the plant with so necessary a material in the composition of woody matter as carbon. It, therefore, appears that the luminous principles are absolutely necessary to the process of ligneous growth—that under the colorific rays they are possessed of the power to decompose carbonic acid, to appropriate the carbon to their own use, and to eliminate the oxygen into the air.

It would appear from the experiments of Dr. Daubeny, Dr. Gardner and Professor Hunt, that the actinic force is not the only one, but there resides within the yellow rays another force entirely different from that of the former. Whether the experiments of these philosophers are true, or whether those of Sennebier accord with facts, is not determined, for the latter philosopher asserts that his experiments prove conclusively, that plants decompose carbonic acid only under the influence of the actinic force. We are inclined to believe that there is really but one force, and that that one is the actinic. The fact of plants decomposing carbonic acid under the luminous rays, only causes us to suspect that the light so obtained was not pure, but that there was a sufficiency of the stimulating rays to induce the decomposition of carbonic acid.

The heat rays appear to impart to foliage those deep red and brown colors so characteristic of the autumnal leaf, while the luminous force is said to give to leaves their bright green. While the

actinic rays are contained in large quantity in the bright sunbeams of summer, their absence in the yellow light of autumn may be the cause of the change of color in foliage, and which is but the commencement of the process of decomposition, initiatory to the fall of the leaf from its parent stem. There is but little doubt but that chlorophyle is produced under the stimulus of the actinic energy, and that when these rays are absent, or partially so, as is the case in the yellow light of autumn, then decomposition of the leaf begins, and hence its colors, varying from yellow and light red to deep brown.

It is only during the growth of the plant that the actinic and luminous rays are required. When the period has arrived for the plant to flower, then the thermic rays are required. These rays probably act as a check upon the chemical rays. As long as these forces, or rather the latter, continue, the plant forms lignine, and accumulates in mass, but when this force is stayed, then the plant applies its energy to the maturation of its flowers. This can be illustrated, if plants, which are growing vigorously, be removed to a situation where the heat rays are most free to act. The plant begins to flower immediately. Here we have an instance of the requirements of the red rays alone. In the leafing of the plant, and in the formation of the chlorophyle, the yellow rays are required, while the seed, most of all, needs the blue rays in order to insure its germination. The red rays, therefore, appear to possess a protective power against the energy of the blue ones. They exalt the oxidation of a silver salt, and prevent the darkening of sensitive paper, which quickly becomes black beneath the energy of the blue rays. In fact these rays not only protect chemical action, but they restore it again, after it has taken place—that is, they restore a compound which has undergone decomposition, or partially so, to its original condition. (Draper.) Flowers are possessed of just the reverse power of leaves. That is, while leaves decompose carbonic acid and give out oxygen, flowers give out carbonic acid, or they breathe like animals. When exposed to the solar rays, they consume large quantities of oxygen; or instead of deoxidation we have reoxidation. This is precisely what takes place on the daguerreotype plate and photographic papers, under the influence of the red rays.

The result of the investigations upon the action of solar light have led to the following conclusions, that:

1. Light prevents the germination of seeds.
2. Actinism quickens germination.
3. Light acts to effect the decomposition of carbonic acid by the growing of plants.
4. Actinism and light are essential to the formation of the coloring matter of leaves.
5. Light and actinism, independent of the calorific rays, prevent the developement of the reproductive organs of plants.

6. The heat radiations, corresponding with the extreme red rays of the spectrum, facilitate the flowering of plants, and the perfecting of their reproductive principles. (Hunt.)

We find that in the spring the actinic rays are the most abundant; but as the seasons progress, and the summer months arrive, the luminous and heat rays, and especially the former, increase in a great degree. In the autumn the luminous or yellow rays rapidly decrease, while the red rays and the heat rays accumulate. This we should anticipate, after having obtained the result of the inquiries stated above.

In fact, the photographer, at a very early period of the art, became cognisant of the fact, that the actinic principle decreased quite rapidly as the seasons advanced. Plants, as has been observed by all, appear to manifest a percipieny in regard to light. They crawl towards it—that is, towards the actinic energies, while they appear to manifest a repugnance for the red rays, and invariably grow from it. (Hunt.)

While plants appear to have a love for the blue and yellow rays, they exhibit a dislike for the red ones. Mushrooms, and the plants of that variety, grow luxuriantly under the yellow rays of the moon, but they would soon perish under the retarding influence of the red rays. These rays, then, appear to exert wholly a retarding influence upon vegetation; and therefore when the season has arrived when the vegetable kingdom shall cease to grow, but shall commence the task of maturing their flowers, then the red rays most abound, and by their influence retard the further growth of the vegetable, and allow it to apply its energies to the maturation of its flowers and seeds.

The contrasting chemical changes which transpire in the same plant through the day, illustrates the wondrous action of light. The *Cacalia ficoides*, during the night, assimilates oxygen, and in the morning is quite acid to the taste. The influence of the solar rays soon act upon the plant, and by noon it is entirely bereft of its acid taste by the loss of the oxygen it had absorbed during the night. The light continues to act upon the plant throughout the afternoon, when oxygen is eliminated, and by night the plant has assumed an intense bitterness. (Liebig.)

COMBINATIONS PRODUCED BY LIGHT.

Chlorine gas will not combine with hydrogen gas at ordinary temperatures in the dark. If, however, a beam of light is allowed to fall upon the mixture, instantaneous combination takes place. This change transpires only through the action of the blue rays, and not at all through that of the red.

Chlorine gas will not combine with carbonic oxide gas, only through the influence of light.

Olefiant gas and iodine combine only in the sunshine.

Many kinds of plate-glass, of a faint violet hue, become purple under the influence of the solar light.

Hyacinths in the light soon change their red hue to one frequently dark brown.

COMBINATIONS ACCOMPANIED BY DECOMPOSITIONS BY LIGHT.

The red rays possess more of the power attributed to decomposition, but this energy resides solely in those rays termed the actinic. Phosphorus, under the influence of the blue or violet rays, is soon changed into the red oxide of that substance. In this case, doubtless, some of the water is decomposed, the phosphorus appropriating the oxygen.

If chlorine is mixed with water, there ensues no disturbance while the solution is in the shade, but if a beam of light be thrown into it, a decomposition of the water quickly ensues, the chlorine forming hydrochloric acid with its hydrogen, and liberating the oxygen.

If an aqueous solution of the chloride of platinum be mixed with lime-water, no change takes place while the mixture is kept in the dark, or is submitted to the red or yellow, or the thermic or illuminating rays; but if the solution is brought under the influence of the chemical rays, a precipitate is quickly formed.

The brown solution of iodine in strong alcohol, which is saturated with sulphurous acid gas, only deposits crystalline sulphur when exposed to the actinic rays.

Chlorine appears to be particularly sensitive to the actinic influence. It will convert anhydrous hydrocyanic acid into solid chloride of cyanogen and hydrochloric acid, only when exposed either to the blue or violet rays, or to white light.

If the oil of olefiant gas in water be placed under the influence of the chemical rays, or to the solar light, it is soon resolved into acetic ether and hydrochloric acid.

Chlorine, under the influence of light, soon converts the oil of olefiant gas into chloride of carbon and hydrochloric acid. Chlorine also decomposes light carburetted hydrogen gas when moist, and forms hydrochloric acid and carbonic acid; but this only takes place in the light.

Many salts dissolved in ether or alcohol, give out oxygen only under the influence of the blue rays, or in white light, by which they are either reduced to a lower oxide, or else to the metallic state. The yellow chloride of the peroxide of uranium, when dissolved in ether, is soon precipitated as the black chloride of the protoxide, by the blue rays.

The chloride of the peroxide of iron, dissolved in ether, is, under the actinic rays, soon decomposed into the chloride of the

protoxide. The red rays exert no influence whatever upon this per-salt.

The chloride of copper, dissolved in ether, is soon reduced to the dichloride by the action of light. This change will not take place in the dark, nor under the red rays.

The bichloride of mercury (corrosive sublimate) is reduced to the protoxide (calomel) by the actinic influence. Red light exerts no action upon this salt.

The red sulph-hydrocyanate of peroxide of iron, is soon converted into the colorless sulph-hydrocyanate of the protoxide by the white or blue light. Even the light from an argand lamp causes this action. (Grotthuss.)

The chloride of gold, dissolved in alcohol or ether, is reduced to the metallic state by the actinic rays. The same change takes place with the ethereal or alcoholic solution of platinum.

If oxalic acid is added to the aqueous solution of the chloride of gold, chloride of platinum, and the ammonia-chloride of iridium, it precipitates the metals and generates carbonic acid. This requires the aid of light. (Döbereiner.)

The aqueous oxalate of peroxide of iron is resolved into carbonic acid, and the oxalate of the protoxide of iron, when exposed to the actinic rays. The red and yellow rays have no action upon this salt.

The red aqueous solution of the oxalate of the sesquioxide of manganese is soon bleached by blue or white light, and is resolved into the oxalate of the protoxide of manganese, and carbonic acid.

The aqueous solution of the tartrate of the peroxide of iron and potash, containing copper, deposits metallic copper on the side of the bottle exposed to the light. Many other organic substances abstract oxygen from metallic salts only through the aid of light. For instance, the oils and charcoal reduce the salts of silver and gold to the metallic form if exposed to light.

The combination of the oxygen of the air with many organic substances, is favored by light. Fabrics, dyed with logwood, safflower, turmeric, and Brazil-wood, soon begin to change color when exposed to the solar beams. This ensues through the action of the light causing the oxygen of the air to combine with the carbon and hydrogen of the coloring matter.

The decoloration of various tinctures, as those of the *Papaver rhæas*, *Cichorium sylvestre*, &c., is solely due to light. Also the decoloration of various oils, such as the linseed, savin, and peppermint, &c., is the effect of light.

The decoloration of the blue solution of iodide of starch in water is effected, with the development of hydriodic acid, by white light. The violet rays counteract the decolorising action of daylight. (Grotthuss.)

DECOMPOSITIONS PRODUCED BY LIGHT.

Salts lose their crystalline water when exposed to light. This happens tardily if they are submitted to red or yellow light, but only beneath the blue with rapidity.

Nitric acid is soon decomposed, if exposed to the light, into nitrous acid and oxygen. The white and blue rays cause this change, but not the others.*

Many metallic oxides are reduced beneath the actinic influence. The oxides of silver and gold are resolved into their metals and oxygen gas. The peroxide of lead is reduced to the red lead, with the loss of oxygen gas. The oxide of mercury is reduced to the metallic state with the loss of its oxygen, and into the red oxide. The red oxide of mercury, under water, is decomposed into the metal, gray oxide and oxygen, under the influence of the blue rays. The protochloride of mercury, dissolved in water, is resolved in the sunshine into dichloride, hydrochloric acid, and oxygen. (Boullay.)

The terchloride of gold, dissolved in water, when exposed to white light, or the blue rays, deposits metallic gold, &c.

REDUCTION PRODUCED BY LIGHT.—THE CHEMISTRY OF PHOTOGRAPHY.

The nitrate of silver, *per se*, is the most stable of the silver salts. It may be preserved unchanged, either in solution or crystalline, for almost any length of time, even if exposed to the light. But if the least organic matter comes in contact with it, then exposure to light, or to the actinic rays, quickly induces decomposition. It is the nature of the acid that preserves the nitrate of silver so permanent, for it appears to be the property of nitric acid to act directly antagonist to light, or to oppose the action of light. To illustrate the accelerating action of organic matter upon nitrate of silver, drop a little upon white paper, and expose to the light, when a blackening of the silver quickly ensues. Nitrate of silver stains the skin upon the same principle. Therefore, while the acid of the nitrate of silver protects the metal from the actinic action, on the contrary organic matter accelerates it. The protecting influence of the nitric acid proceeds from the great facility with which it yields oxygen to other substances, while the action of the organic matter is to neutralise this effect. The accelerating effect of organic matter is gen-

* The radical ethyle is obtained only by the action of light. It is obtained by the iodide of ethyle, which is introduced into an inverted glass globe, which is previously filled with mercury. This is then exposed to the rays of the sun, when the iodine combines with the mercury, and the ethyle is separated in the form of a gas. If water should be present, the hydride of ethyle is formed. There is no doubt but that the other alcohol radicals could thus be isolated, substituting their iodides for that of the ethyle.

erally proportionate to the attraction which it has for oxygen. The nitric acid is antagonist to this action, from its tendency to yield up oxygen to the organic body, and thus to retard, or to prevent, the reduction of the silver.

In every instance, in our future remarks upon the action of light, we would wish to be understood as referring wholly to the *actinic* rays, for it is those rays alone which produce the phenomena attributable to light by photographers. The actinic rays, or those most refrangible, and therefore most closely associated with the violet and blue rays, may be regarded as the *reducing* rays, and which produce the chemical effects desired by those who take pictures by light. By the general term of *light*, we therefore refer to these rays.

Although the nitrate of silver is rendered sensitive to light by the association of organic matter with it, still it is not sufficiently sensitive to answer the purpose of the photographer. The iodide, chloride, and bromide of silver, are still more sensitive compounds, but before they can be rendered available for the purposes of photography, they should be combined with organic matter, such as possesses the quality of absorbing oxygen with facility. However, that the sensitiveness of the chloride, or iodide, or bromide shall be aided, a small quantity of the nitrate is generally mixed with them.

The rationale of the action of light upon a silver salt—as for instance the chloride—is explained by the fact, that the actinic rays are possessed of the property of decomposing the salt, or of removing from it a part, or the whole, of the chlorine. If, for illustration, the chloride of silver is suspended in water, and submitted to solar light for several days, it becomes dark, and the water will be found to contain a considerable quantity of acid. This acid is the hydrochloric, caused by the chlorine *in statu nascenti* decomposing the water, and forming the above acid with its hydrogen. Although there is a strong affinity between chlorine and silver, still the powerful action of light disrupts the two elements, and thereby causes the formation of a strong acid. Now this blackened chloride of silver, which contains less chlorine than the white, possesses properties different from the latter, for it is insoluble in the hyposulphite of soda, while the white chloride is. It is quite probable that while the white chloride of silver is the protochloride (Ag Cl), the dark salt is the dichloride ($\text{Ag}_2 \text{Cl}_2$). But in the process of photography the silver salt is generally reduced to the metallic state. This is accomplished through the mysterious action of light, although reagents are now resorted to for the purpose of accelerating and continuing, what light has only really commenced. These reagents act solely through their tendency to absorb oxygen, for any body which possesses the least avidity for oxygen if brought in contact with the oxides of the noble metals, as those of gold, platinum, and silver, reduce

them to the metallic state by absorbing the oxygen of these oxides. But it is only those portions of the salt which have been exposed to light that they reduce, while those portions upon which the sun's rays do not impinge, are left wholly unreduced. This opaque deposit forms the image, while the portion upon which light has not impinged is wholly unreduced.

To illustrate the reduction of a salt of silver, take a little of the ammonia-nitrate of silver, and add to it in solution some solution of pyrogalllic acid. This organic acid possessing a great affinity for oxygen, abstracts it from the oxide of silver present, and the metal is reduced. This deposition proceeds from the fact that although the oxide of silver is soluble in ammonia, the metal is not, and therefore the precipitation of silver.

How then is it, that if the reduction of a metal depends upon the absorption of oxygen, that an organic body which has a strong affinity for oxygen reduces the haloid salts, which contain none of that element? This certainly would not be the case, were there not a simultaneous decomposition of water. This water consists of oxygen and hydrogen. The former is absorbed by the organic body, while the latter combines with the salt-radical to form an acid. This reaction is proved to take place when the chloride of gold in solution is mixed with gallic acid. The gold is quickly precipitated, while the water contains free hydrochloric acid.

The *Developer*,—as the deoxidising substance which is used for the reduction of the silver salt is termed,—acts only in continuing what the light has already begun. It would require some time for the light to produce the full effect needed, as in that case the salt would be reduced by degrees. This is the case when the free nitrate of silver and organic matter is present, associated with the iodide or chloride of silver. But it is ascertained, that if the light has impinged upon the sensitive surface only just so long as to start the peculiar action it induces in the salt, that the *developer* continues that action. By this means a person is not necessitated to sit for a comparatively lengthy time for a picture, as the developer finishes what the light had begun.

The protosulphate of iron is used as a developer. It is an energetic one, being by the absorption of oxygen, converted into the sesquioxide (Fe_2O_3).

The gallic and pyrogalllic acids are converted into more highly oxidised substances, but which have not been sufficiently examined to enable us to determine their nature.

Although the image taken upon the paper or plate is itself permanent, still it is necessary that the unchanged silver which surrounds it should be dissolved away, or the diffused light will gradually blacken it likewise. This is done by the "fixing agents," which in the case of the chloride and iodide of silver, are ammonia, the alkaline chlorides, the alkaline iodides, the alkaline hyposul-

phites, and the alkaline cyanides. The hyposulphite of soda and the cyanide of potassium are the two agents generally resorted to.

Since the collodion, or pyroxyline pictures, have undergone such marked improvements, they have attracted considerable attention. From the fact that by means of these collodion pictures upon glass, negatives can be taken, from which any number of positives can be obtained, they have become very desirable. As it is not our purpose to enter into a complete description of the various photographic processes, and the methods of preparing the chemicals for those purposes, we would simply mention that collodion is the material upon which the negatives and ambrotypes are taken. The latter pictures have lately been patented, but they are not by any means a new thing, as Mr. Hawkins, of Cincinnati, and the author, took them eight years ago.

The collodion, or pyroxyline, is gun-cotton dissolved in the sulphuric ether of commerce, which must, however, be purified, and about one-third of strong alcohol added. The author has ascertained that about one half of a saturated ethereal solution of gutta percha added to the collodion, greatly improves the tone of the picture, and adds to its sensibility.

We will close this article upon Light by giving a few of the photographic processes, as illustrative of the decomposing action of the actinic rays.

HARDWICK'S POSITIVE COLLODION PROCESS.—There are a variety of formulæ for taking pictures on collodion, but the one of Mr. Hardwick is perhaps the best. We have found it all that is desirable.

A. The Collodion.—Take of purified ether, sp. gr. .720, five drams; alcohol, sp. gr. .825, three drams; soluble cotton, one and a half grains; pure iodide of potassium, one and a half grains. The exact quantity of soluble cotton which will be required cannot be stated with precision, since some samples produce a far more glutinous solution than others. The rule to be followed is to keep the texture of the fibre as slight as possible, since with so small an amount of iodine a great improvement in the definition and sharpness of the image is produced in that way. If the quantity specified yields a solution like water, running down the neck of the bottle in the attempt to pour it on the plate, it may be increased.

The quantity of the iodide of potassium must be regulated by the appearance of the film after dipping in the bath. It should be a pale blue, and very transparent. If the room is dimly illuminated the film will scarcely be seen distinctly, and must therefore, after washing, be brought out to the light for inspection.

It is necessary that the ether and alcohol in this collodion should be unusually pure, or it will be impossible to work with such a film. The purity of the materials may be measured by the rapidity of coloration on iodising the collodion. If, when iodised with iodide

of potassium, it begins to change visibly in two or three minutes, and attains to a yellow color in a quarter of an hour, the probability is that the half tones of the resulting positive will be inferior. In that case a very fair result may still be obtained by adding more iodide, to enable the film to stand the retarding effects of the impurity. Indeed, by proper management in this particular, the operator will seldom be liable to disappointment, even although the quantities laid down should be found to be too small.

This collodion cannot be kept over a month. When it has turned a deep brown, then it has lost its virtue, and the iodine must be removed. This can be done by placing a piece of silver foil in the bottle, and allowing it to remain there as long as required. In this case iodide of silver is formed, which dissolves in the alkaline iodide.

If pure ether and alcohol cannot be procured, the formulæ may be modified thus: rectified ether, six drachms; spirits of wine, two drachms; soluble cotton, two and a half grains; iodide of potassium, two and a half grains. This film should be opalescent and tolerably transparent.

B. The Nitrate Bath.—Take of nitrate of silver crystallised, but not fused, twenty-one grains; distilled water, one ounce; to every hundred grains of the nitrate of silver, one and a half grains of iodide of potassium should be added. The deposit of iodide of silver will dissolve upon stirring the solution. There should likewise be added to this solution one grain of carbonate of soda to each hundred grains of the nitrate of silver, in order to neutralise the excess of nitric acid. Should this solution become acid after the immersion of some forty or fifty plates, the acid should be neutralised with alkali.

If a small proportion of the acetate of silver is added to the bath, it will not be necessary to preserve the solution chemically neutral. The acetate of silver substitutes free acetic acid for nitric, and a minute quantity of acetic acid does no injury.

C. The Developing Fluid.—Take protosulphate of iron, pure and crystallised, twelve to sixteen grains; glacial acetic acid, eight to twelve minims; distilled water, one ounce.

D. The Fixing Solution.—Take cyanide of potassium, one or two grains; water, one ounce. The cyanide of potassium is superior to the hyposulphite of sodium for fixing positives, as it is less liable to injure the purity of the white color. The cyanide solution should be used as dilute as possible.

THE INSTANTANEOUS PROCESS OF MR. FOX TALBOT.—1. Take the most liquid portion of the white of an egg, rejecting the rest; mix it with an equal quantity of water; spread it very evenly upon a plate of glass, and dry it at the fire. A strong heat may be used without injuring the plate. The film of dried albumen ought to be uniform and nearly invisible.

2. To an aqueous solution of nitrate of silver add a considerable

quantity of alcohol, so that an ounce of the mixture may contain three grains of the nitrate.

3. Dip the plate into this solution, and let it dry spontaneously. Faint prismatic colors will then be seen upon the plate.

4. Wash with distilled water to remove any superfluous portions of the nitrate. Then give the plate a second coating of albumen similar to the first, but in drying avoid heating it too much, which would cause a commencement of decomposition of the silver.

5. To an aqueous solution of the protoiodide of iron add, *first*, an equal volume of acetic acid, and then ten volumes of alcohol. Allow the mixture to repose several days.

6. Into the iodide thus prepared and modified, the plate is dipped for a few seconds.

7. A solution is made of nitrate of silver containing about seventy grains to the ounce of water. To three parts of this add two of acetic acid. Then, if the prepared plate is rapidly dipped once or twice into this solution, it acquires a great degree of sensibility, and ought then to be placed in the camera without delay.

8. The plate is withdrawn from the camera, and in order to bring out the image, it is dipped into a solution of protosulphate of iron, containing one part of the saturated solution diluted with two or three parts of water. The image appears very rapidly.

9. Having washed the plate with water, it is now placed in a solution of hyposulphite of soda, which in one minute causes the image to brighten up exceedingly, by removing a kind of veil which previously covered it.

10. The plate is then washed with distilled water, and the process is terminated.

THE CHROMATYPE.—If to a solution of sulphate of copper, we add a solution of the neutral chromate of potash, a very copious brown precipitate falls, which is a true chromate of copper. If this precipitate, after being well washed, is added to water acidulated with sulphuric acid, it is dissolved and a dichromate solution is formed, which, when spread upon paper, is of a pure yellow. A very short exposure of the paper washed with this solution is quite sufficient to discharge all the yellow from the paper, and to give it perfect whiteness. We may bring out the picture by placing the paper in a solution of carbonate of soda or potash,—by which all the shadows are represented by the chromate of copper,—or by washing the paper with nitrate of silver.

If the chromate of copper is dissolved in ammonia, a beautiful green solution results, and if applied to paper acts similarly to that just described. (Hunt.)

HUNT'S FERROTYPE.—Good letter-paper is washed over with the following solution, viz: Five grains of succinic acid (it is important that succinic acid free from any oil of amber or adventitious matter should be obtained) are to be dissolved in one fluid-

ounce of water, to which are added about five grains of common salt, and half a drachm of mucilage of gum-arabic. When dry, the paper is drawn over the surface of a solution of sixty grains of nitrate of silver in one ounce of distilled water.

Allowed to dry in the dark, the paper is now fit for use. It is of a pure white, retains its color, and may be preserved for a considerable time in a portfolio, until wanted for use. When the paper is taken from the camera, nothing is visible upon it; but by attending to the following directions the latent picture will quickly develop itself. Having mixed together about one drachm of a saturated solution of protosulphate of iron and two or three drachms of mucilage of gum-arabic, pour a small quantity into a flat dish. Pass the prepared side of the paper taken from the camera rapidly over this mixture, taking care to insure complete contact in every part. If the paper has been sufficiently impressed, the picture will almost immediately appear, and the further action of the iron must be stopped by the application of a soft sponge and plenty of clean water. Should the image not appear immediately, or be imperfect in its details, the iron solution may be allowed to remain upon it a short time, but it must then be kept disturbed, by rapidly but lightly brushing it up, otherwise numerous black specks will form and destroy the photograph. Great care should be taken that the iron solution does not touch the back of the picture, which it will inevitably stain, and, the picture being a negative one, be rendered useless as a copy. A slight degree of heat will assist the development of the image where the time of exposure has been too short. The picture should be carefully washed to take off any superficial blackness, and may then be permanently fixed by being soaked in water to which a small quantity of ammonia, or better still, hyposulphite of soda has been added. The paper must again be well soaked in clean water, to clear it from the soluble salts, and may then be dried and pressed.

WOOD'S CATALYSOTYPE.—Take of syrup of iodide of iron, distilled water, of each two drachms; tincture of iodine, ten or twelve drops; mix. First, brush this over the paper, and after a few minutes, having dried it with blotting-paper, wash it over in the dark (before exposure to the camera) with the following solution by means of a camel's hair pencil. Take of nitrate of silver, one drachm; pure water, one ounce; mix. This makes a negative picture from which good positives on paper can be taken.

To fix the picture, let it be washed first in water, then allowed to remain for a few minutes in a solution of iodide of potassium (five grains to the ounce of water), and washed in water again. When this picture blackens in the dark, there is too much caustic used; when it remains yellow, or when it is studded with yellow spots, too much iodine. When marked with black spots, too much iron. It is necessary to mention these on account of the varying strength of the materials employed.

HUNT'S SENSITIVE PAPER.—Highly glazed letter-paper is washed over with a solution of one drachm of nitrate of silver to the ounce of distilled water. It is quickly dried, and a second time washed with the same solution. It is then, when dry, placed for a minute in a solution of two drachms of iodide of potassium to six ounces of water, placed on a smooth board, gently washed by allowing some water to flow over it, and dried in the dark. Paper thus prepared may be kept for any length of time, and is at any time rendered sensitive by simply washing it over with a solution of one drachm of the ferrocyanide of potassium to an ounce of water. These papers, washed with the ferrocyanide and dried in the dark, are absolutely insensible, but they may at any moment be rendered sensitive by merely washing them with a little clear cold water. Papers thus prepared are rendered quite insensible by being washed over with the above hydriodic solution. They are, however, best secured against the action of time by a solution of ammonia.

THE FLUOROTYPE.—This is so called from the use of the salts of fluoric acid.

{ Take Bromide of potassium, - - - - -	20 grains.
{ Distilled water, - - - - -	1 ounce.
{ Fluoride of sodium, - - - - -	5 grains.
{ Distilled water, - - - - -	1 ounce.

Mix a small quantity of these solutions together when the papers are to be prepared, and wash them over once with the mixture, and when dry, apply a solution of nitrate of silver, sixty grains to the ounce of water. These papers keep for some weeks without injury, and become impressed with good images in half a minute, in the camera. The photograph should then be soaked in water for a few minutes, and then placed on a slab of porcelain, and a weak solution of the protosulphate of iron, to which is added a little acetic or sulphuric acid, should be brushed over it. The picture soon acquires an intense color, which should then be stopped directly by plunging it into water slightly acidulated with muriatic acid, or the blackening will extend all over the paper. It may be fixed by being soaked in water, and then dipped into a solution of hyposulphite of soda, and again soaked in water.

BINGHAM'S MODIFIED PROCESS.—The protochloride of tin possesses the property of reducing the salts both of silver and of gold. A paper is prepared with the bromide of silver, and previously to exposing it to light, it is washed over with a very weak solution of the chloride of tin. The action of light upon the paper is exceedingly energetic. It is almost instantly blackened, and a copy of a print is obtained in a few seconds.

HUNT'S PHOTOGRAPHIC PAPER.—Select the most perfect sheets of well-glazed satin post, quite free from specks of any kind. Placing the sheet carefully on some hard body, wash it over on one side by

means of a soft camel's hair pencil, with a solution of sixty grains of the bromide of potassium, in two fluid-ounces of distilled water, and then dry quickly by the fire. Being dry, it is again to be washed over with the same solution, and dried as before. Now a solution of nitrate of silver, one hundred and twenty grains to the ounce of water, is to be applied over the same surface and the paper quickly dried in the dark. In this state the papers may be kept for use. When they are required, the above solution is to be plentifully applied, and the paper placed wet in the camera. After a few seconds the light must be shut off, and the camera removed to a dark room. There is nothing yet visible on it. Lay it aside in perfect darkness until quite dry, then fix it in the mercurial vapor box, and apply a gentle heat to the mercury. The picture will soon begin to develop. The vaporisation must now be suddenly stopped, and the photograph removed from the box. Place the paper away in the dark, and allow it to remain there for some hours, when the picture will come out in all of its details. The nitrate of silver must now be removed from the paper by washing in soft water. When the picture has been dried, wash it quickly over with a soft brush dipped in a warm solution of the hyposulphite of soda, and then well wash it for some time that the salt may be thoroughly washed out. The picture is now fixed, and may be used to procure positive pictures, many of which may be taken from one original.

HUNT'S PAPER DAGUERREOTYPES.—To prepare this paper, soak that of very firm texture, not too much glazed, in a weak solution of the muriate of ammonia. It must then be wiped with clean cloths, and carefully dried. The paper is then dipped into a weak solution of the nitrate of silver, and the small bubbles which form on its surface are carefully removed with a camel's hair pencil. When the paper is nearly, but not quite dry, it must be exposed in a closed vessel to sulphuretted hydrogen gas, slowly formed from the sulphide of antimony and hydrochloric acid: in a few minutes it will become of an iron-brown color, having a fine metallic lustre. It is again to be passed through a solution of silver, somewhat stronger than the first, and dried, taking care that no shadow falls on the paper whilst it is drying. It is then a second time submitted to sulphuration, and by careful management, the process is now generally completed. If, however, the paper is not considered to be sufficiently dark, it must be once more washed in the solution of silver, and again subjected to the action of sulphuretted hydrogen. If the above paper be allowed to remain in the sulphuretted hydrogen gas after the maximum blackness is produced, it is again whitened with some quickness. This may be accounted for in two ways: the gas may be mixed with a portion of muriatic acid vapor, or a quantity of chlorine sufficient to produce this effect may be liberated from the preparation on the paper to react on the sulphide of silver. The perfection of these papers consists in having a deep

black ground to contrast with the mercurial deposit, by which means the pictures have the advantage of being seen equally well in all positions. The sulphuretted paper may be rendered sensitive in the same manner as the plates, by exposure to the vapor of iodine. The following process Professor Hunt prefers. A saturated solution of any salt of iodine is made to dissolve as much pure iodine as possible, and of this liquid two drachms are mingled with four ounces of water. Care is required that only one side of the paper is wetted, which is by no means difficult to effect, the fluid is so greedily absorbed by it. All that is necessary being a broad shallow vessel to allow of the paper touching the fluid to its full width, and that it be drawn over it with a slow, steady movement. When thus wetted, it is to be quickly dried by a warm, but not too bright fire—of course daylight must be carefully excluded. Papers thus iodated do not lose their sensitiveness for many days, if carefully kept from light. Although the picture by the above process is very perfect, still it is susceptible of vast improvement by the following process. Dip one of the pictures formed on the sulphuretted paper, into a solution of corrosive sublimate. The drawing instantly disappears, but after a few minutes it again appears, and gradually becomes more distinct than it was before. Delicate lines before invisible, or barely seen, are now distinctly marked, and a rare and singular perfection of detail given to the drawing. If the drawing remains too long in the solution, the precipitate adheres to the dark parts, and destroys the effects. When these papers are prepared with due care they are extremely sensitive, and if used for copying engravings, during bright sunshine, the effect is instantaneous. In the weak light of the camera a few minutes during sunshine is quite sufficient for the production of the best effects. One great advantage of these pictures over those procured on the plated copper is, that the mercury does not lie loosely as on the tablets, but is firmly fixed, being absorbed by the paper—therefore these pictures may be kept without injury in a portfolio. If, instead of immersing the paper in a vessel full of sulphuretted hydrogen gas, a stream of the gas is made to play upon it, it assumes a most richly iridescent surface. The various colors are of different degrees of sensibility, but for surface drawings they may be used; and in copying of leaves and flowers, beautiful pictures, which appear to glow with the natural colors, are produced.

TALBOT'S CALOTYPE PAPER.—A sheet of the best writing-paper, of smooth surface and close, even texture, is washed, by means of a soft brush, with a solution of fifty grains of crystallised nitrate of silver to one ounce of distilled water, and then dried—either by holding it at some distance from the fire, or by spontaneous evaporation in the dark. When dry, or nearly so, it is immersed for two or three minutes in a solution of iodide of potassium containing five hundred grains of that salt to a pint of water. It is then immersed

in water for a quarter of an hour, lightly dried with blotting-paper, and then dried at the fire. All these operations are best performed by candlelight. The paper thus prepared is called iodised paper; it is not sensitive to light, and may be preserved for any length of time without change. When required for use, it is to be washed with a liquid prepared by dissolving one hundred grains of crystallised nitrate of silver in two ounces of distilled water, adding to the solution its own volume of strong acetic acid, and mixing the liquid thus formed with from one to twenty volumes of a saturated solution of crystallised gallic acid in cold distilled water. It is best to mix these liquids in small quantities at a time, as the mixture does not keep long without spoiling. This liquid (the gallo-nitrate of silver) is to be washed over the paper on the side previously iodised, and after the liquid has been allowed to remain on it for half a minute, it must be dried lightly with blotting-paper. This operation requires the total exclusion of daylight. The paper prepared in this manner is exquisitely sensitive, exposure of less than a second to diffused light being quite sufficient to produce a decided effect upon it. The calotype picture is a negative one, but positives may be taken from it by juxtaposition. These pictures have, however, been superseded by those on glass and collodion. The first collodion picture that we have any account of was taken at Cincinnati in 1847, by Mr. E. C. Hawkins, assisted by the writer of this article. If others were taken previous to that time, we have no knowledge of it.

THE DAGUERRETYPE.—These pictures are taken on a metallic plate of copper, upon which is a thin stratum of pure silver, the latter occupying about one-fortieth of the weight of the copper. These plates require to be cleaned and polished with the greatest nicety, otherwise the picture will prove dull and indistinct. Most of the failures occur through the want of a proper regard to this stage of the process. After the cleaning and polishing is complete, the plate is placed in a box containing iodine. This iodine is sprinkled over the bottom of the box, and a thin paper is spread over it, so that the vapor of the iodine may be equally distributed over the plate. The plate is generally allowed to remain over the iodine until it assumes a golden yellow hue. It is then transferred to the bromine box. The bottom of this box contains a layer of brominated lime. Some persons use chlorine associated with the bromine, but whether there is an advantage gained by it is doubtful. The plate is kept over the bromine until it becomes of a steel-gray color, when it has reached its highest degree of sensitiveness and susceptibility of taking a sharp impression, and of producing the most pleasing tone.

The plate is now transferred to the camera, and after having been submitted to the action of light a sufficient time, it is placed in the mercury bath. A heat of 140° F. is applied to the mercury, and the picture soon commences to develope. When this is accomplished the plate is placed in a solution of hyposulphite of soda,

which soon removes the unaltered iodide, or bromo-iodide of silver, and the picture is "fixed." Before, however, it is allowed to pass into the hands of its purchaser, it is gilded by pouring upon it a solution of chloride of gold, and gently heating the under surface of the plate with a spirit-lamp, until the metallic gold, reduced by the galvanic action of the plate, is precipitated in an exceedingly thin, transparent film, over the entire surface of the picture. This preserves the picture from the action of the air.

We are of the opinion that Daguerreotype pictures are not durable. We know that they soon fade if not covered with gold, and as this stratum of gold is infinitesimally thin, it will in time oxidise off, and leave the picture exposed to the air. It is not to be supposed that so delicate a fabric as one of these pictures should be durable, upon so unstable a foundation as two plates of metal, between which,—so closely juxtaposed and so antagonistic in their electrical relations—there is such great liability to galvanic action. We think the day is not far off when the Daguerreotype picture will be entirely superseded by those beautiful and equally delicate positive pictures taken on collodion, or perhaps better still, on gutta percha.

The subject of Light, when treated in detail, is a voluminous one, and would occupy much more space than is allowed in this volume, or which would be consistent with an elementary work upon chemistry. We have attempted to present the most prominent facts connected with Light, while we have entirely passed over the details which, although possessed of the greatest interest and importance, would occupy entirely too much space for our little volume. Before closing the subject of Light we give the latest and best process for the taking of pictures on glass, both *Positives (Ambrotypes)* and *Negatives*. We also give the new *Collodio-albumen* process.

POSITIVES ON GLASS, OR THE AMBROTYPE.

Before entering into the manipulation for the production of positives on glass, it is necessary that the amateur should possess a clear idea of the meaning of the terms "positive" and "negative."

A positive collodion picture may be defined to be a photograph giving a natural representation of the object it is intended to represent when viewed by reflected light.

A negative picture, on the contrary, when viewed by reflected light, gives but an imperfect representation of the object from which it was taken, having the high lights of the picture obscure, and of a brown color, without any apparent definition of middle tints, or the light and shades merging into one another with abruptness; but, if viewed by transmitted light, the lights and shades are reversed—representing all the pure whites of the object by perfect blackness, the blacks by perfect transparency, and the middle tints of various gradations of tone in the same *inverse* order, according as the parts

represented are more or less approaching the white or sombre shades.

The production of positive pictures has of late been much followed, both by amateurs and professional photographers, from the ease and rapidity of their production, the delicacy of the detail, and the brilliancy of the resulting picture, which rivals daguerreotypes in the representation of minutiae; although, unlike the daguerreotype, it may be viewed in any light. The apparatus necessary for the production of positive pictures is not essentially extensive, consisting of a camera, lens, camera stand, glass or gutta-percha bath and dipper, glass plates, and box to contain them, graduated measure, funnel, filtering paper, scales and weights, washing tray, leveling stand, pocket level, stirring rod; and, of chemicals, a supply of positive collodion, with a proportionate quantity of iodising solution, nitrate of silver, acetic acid, protosulphate of iron, nitrate of barytes, cyanide of potassium, crystal varnish, black varnish, and distilled water, together with a small quantity of nitric acid, ammonia, and tripoli.

Before entering into the description of the manner of taking photographs, a few words on the manufacture of gun-cotton and collodion will be necessary.

The preparation of gun-cotton and collodion are operations that few amateurs would venture on, as they require considerable care and attention to insure success; still, circumstances may occur in which a knowledge of the mode of manipulation may be useful.

To make Gun-Cotton.—Take four ounces of nitrate of potash, powdered and thoroughly dry, and place it in a porcelain capsule holding about one pint, then pour over it five ounces, by measure, of the ordinary commercial sulphuric acid (sp. gr. 1.840), stir well together with a glass rod, and then immerse, in small portions at a time, two drams of fine cotton, previously dried; continue the stirring with the glass rod, so that every portion of the cotton becomes thoroughly impregnated with the acid mixture. Occasionally press down any portion of cotton which may rise above the liquid, and, when ten minutes have elapsed, remove the cotton by the aid of two glass rods into a large vessel of water; stir briskly, and repeatedly change the water, wringing the cotton as dry as possible between each change, until every trace of acid is removed. Then, as a still further precaution to the perfect removal of the last traces of the acid, wash the cotton with two or three washings of boiling water; then wring dry; pull out the fibres, and dry it thoroughly by a very gentle heat, always bearing in mind that this substance is more or less explosive, and therefore must not be brought too near a candle or fire. When perfectly dry it may be preserved for any length of time, if kept in a closely-stoppered bottle.

Should the gun-cotton have been correctly prepared, it will completely dissolve in rectified ether, forming a clear solution, which,

when poured on a glass plate, and the excess drained off, dries perfectly transparent, free from specks or milkiness of the film.

Preparation of Collodion.—Put one ounce and a half of rectified ether (sp. gr. .750) in a two-ounce stoppered bottle, add to it ten grains of gun-cotton, and agitate frequently to facilitate the solution. If the gun-cotton is good, it will dissolve in a few minutes, and, in the generality of cases, produces a collodion of the necessary amount of thickness, but the proportion may be varied until the desired viscosity is obtained.

Collodion of the proper thickness, when iodised and poured on a glass plate, and then drained off, should dry to an even transparent film, free from ridges, and flowing easily over the plate, without an excessive tendency to run off.

A sufficient quantity of this collodion may be made to last for months, and, by being allowed to stand undisturbed, any particles of undissolved cotton will sink to the bottom of the bottle, allowing the upper portion to be decanted off perfectly clear.

The collodion thus made has to be iodised to render it fit for photographic purposes. Various formulæ are published for the manufacture of the iodising compound, but the writer has found none succeed so well, in the hands of the unprofessional, as a mixture of the following solution :

Take Iodine	:	:	:	:	:	4 grains.
Alcohol	:	:	:	:	:	1 ounce.

Dissolve, and label the bottle containing this solution, "Solution of Iodine."

Now, for the iodising mixture, take—

Iodide of potassium	:	:	:	:	:	12 grains.
Solution of iodine	:	:	:	:	:	4 drops.
Alcohol	:	:	:	:	:	1 ounce.

Add the iodide of potassium to the alcohol, and shake frequently until dissolved, then add the solution of iodine, filter through filtering-paper, and preserve in a closely-stoppered bottle, labelled, "Iodising Mixture." This solution will keep good any length of time.

In order to iodise collodion with this mixture, all that is needed is to add half an ounce of the iodising mixture to one and a half ounce of collodion, and, after shaking well together, allowing the bottle containing it to remain undisturbed for at least twelve hours, in order that any insoluble matter may settle to the bottom; and, before being used, it is advisable to pour off the clear portion of the iodised collodion into a clean and perfectly dry bottle.

As collodion, when iodised as above stated, does not keep good more than three weeks, it is advisable not to iodise more than will

be used in a fortnight. The best pictures are taken with collodion that has been iodised from two to ten days, after which time it begins to lose its sensibility, and ultimately becomes useless, from the length of exposure necessary to obtain a picture.

The production of positive pictures may be divided into nine distinct heads:

1. Cleaning the plate.
2. Coating the plate.
3. Exciting the plate.
4. Arrangement of the sitter.
5. Focusing.
6. Exposure in the camera.
7. Developement of image.
8. Fixing.
9. Finishing the positive picture.

1. *Cleaning the Plate.*—The glass best adapted for receiving positive pictures is termed “patent plate;” this can be obtained ready cut, and the edges ground to prevent injury to the fingers, of the usual sizes required by photographers.

The size of picture produced is, to a great extent, governed by the size and focal length of the lenses employed. If a one inch and three-quarters portrait lens is to be used, plates four inches by three inches may be chosen; if a two inches and three-eighths portrait lens, five inches by four inches; and if a three and a quarter inch portrait lens, six inches by five inches.

The best substance for removing stains, grease, &c., from glass plates is a mixture, made as follows:

Cyanide of potassium -	-	-	-	-	-	2 drams.
Tripoli -	-	-	-	-	-	2 drams.
Water -	-	-	-	-	-	2 ounces.

Dissolve the cyanide of potassium in the water, then add the tripoli, and shake well together.

Having selected a suitably sized glass plate, pour a teaspoonful of this mixture over the centre of the plate, and, with a pledget of linen, well rub it over every part, back and front; hold it under a tap to rinse, or dip it in a basin of cold water, so as to remove every particle of the mixture; then, without waiting for the plate to dry, remove every trace of moisture with a linen cloth, and polish with another cloth, holding the plate by the cloth, and not by the hand, so as to prevent the slightest grease being communicated to it.

The cloths employed should be of a material sold as “fine diaper,” and must be well freed from grease or soap, by careful washing in soda and water, then plentifully rinsed in water and dried; also the one used as a polisher should be kept quite dry. Occasional breathing on the plate during the polishing, and then holding it obliquely, so that the moisture deposited may be seen by reflected light, will serve to point out whether a plate is clean or not. If the moisture

of the breath is deposited in patches, more cleaning is required; but if the deposit is evenly spread over the whole surface, it may safely be considered as clean; but too much care cannot be bestowed on this part of the process, for the slightest impurity, although now apparently invisible, renders itself palpable in the after processes, to the complete destruction of the finer details of the finished picture.

Glass plates, after being once used, require a more careful cleaning than new plates, before being again employed, and as the film is easier detached whilst still moist, it is advisable not to allow them to dry, but to place all plates that are to be used again in a vessel of water before they become dry, and allow them to remain immersed until required for cleaning.

2. *Coating the Plate.*—Before proceeding to coat the plate, it is necessary that the collodion should have been mixed with the iodising solution at least twelve hours, and allowed to remain undisturbed, so that any sediment which forms may have subsided; and, in all cases, the dust and dried crust of the collodion, which may adhere to the neck of the bottle, must be carefully removed, otherwise spots and striæ will be produced on the plate.

If particles of dust are floating in the air of the operating room, it will be useless to attempt to coat a plate, as these will deposit themselves on it and appear as fine filaments, which serve as a nucleus for a spreading stain in the after process. For this reason it is recommended to clean the plates in another room, so as not to disturb the atmosphere of the operating room by this operation.

Now ascertain that the glass plate is scrupulously clean and free from finger-marks; remove any adherent particles of dust by friction, with chamois leather. Hold the plate horizontally by the corner with the finger and thumb of the left hand, remove the stopper from the iodised collodion bottle, and holding it in the right hand, pour the collodion on to the glass plate in sufficient quantity to form a circular pool extending nearly to the corners. Now incline the plate so that the fluid may flow to each corner (avoiding the thumb if possible), and drain off the superfluous collodion back into the bottle, by holding the plate in a vertical direction. Give the plate a rocking motion on the neck of the bottle, by raising and depressing one corner, so that the lines or furrows which are formed may run one into the other; continue this until the covered surface of the plate appears set from the evaporation of the ether; when this takes place, the plate is ready to be rendered sensitive.

As the vapor of ether is highly volatile and inflammable, great care must be used in not approaching a light near an open bottle of this fluid or of collodion, as serious accidents may occur from any negligence in this particular.

Should the iodised collodion, from the evaporation of its volatile

constituent, become too thick to flow evenly over the plate, it may be rendered thin by the addition of ether.

BATH SOLUTION.

Nitrate of silver, in crystals,	-	6	drams.
Distilled water,	- - -	12	ounces—dissolve and filter.

In order to ascertain the fitness of this solution for photographic purposes, two other solutions and a book of test-paper will be required. The solutions are:

1st. Nitric acid,	- - -	half a dram.
Distilled water,	- - -	2 ounces—mix, and label
"Dilute nitric acid."		
2d. Ammonia,	- - -	half a dram.
Distilled water,	- - -	2 ounces—mix, and label
"Dilute ammonia."		

In order that the "Bath solution" may be in a condition to give good pictures, it must contain a *slight trace of free acid*, and it frequently happens that the nitrate of silver employed contains just the required quantity; but occasionally it contains none, and sometimes an excess. Therefore it becomes evident we cannot depend on always making our solution contain just the amount required and no more. We therefore take a leaf of test-paper, and apply a drop of the bath solution to its colored surface. If the violet color of the test-paper remains unchanged after the solution has been applied one minute, the solution contains no free acid, and in chemical language is said to be "neutral."

Add one drop of dilute nitric acid to each six ounces of bath solution, shake well together, and apply another drop to the test-paper. If the solution was exactly neutral in the first instance, the color of the paper will now be changed to a pale red, and the bath may be considered fit for use; but should the paper, when the solution is applied, not change to a pale red, add another drop of dilute nitric acid to each six ounces until the desired tint is produced.

Should the test-paper, when first moistened, change to a bright red, the bath solution is too acid, to neutralise which, add dilute ammonia, drop by drop, shaking well between each addition, and testing with test-paper until the color of the paper is unchanged after the solution has been in contact with it one minute; when such is the case, add one drop of dilute nitric acid to each six ounces of solution, shake well together, and it is fit for use.

Should the test-paper become blue after being wetted, too much ammonia has been employed, and dilute nitric acid must be added, drop by drop, applying the solution to the test-paper between each addition, until the color remains unchanged, and the solution is neutral; then add one drop of dilute nitric acid to each six ounces of solution, and it is fit for use.

This amount of free acid is ample for working with almost every

kind of collodion; but in some cases, where extreme rapidity of action is required, half this quantity is sufficient. The addition of free acid to the bath solution is added to prevent "fogging" of pictures produced by it, which is caused by a reduction of the silver on those parts which constitute the deep shade, giving the picture the appearance of being veiled by a dense fog; but too much acid is equally prejudicial, giving rise to a necessity for prolonged exposure of the plate in the camera, and often to an irregular action of the developing fluid.

It is necessary to test the bath with test-paper after the immersion of each 30 or 40 plates, in order to ascertain if it contains the necessary amount of free acid, and should it be found either in excess or too little, it must be remedied as above described. This testing must, in no case, be done hurriedly, but a drop must be applied to the test-paper, and allowed to remain in contact one minute, then shaken off, and the color of the wetted part noticed; and I must caution the amateur not to look for excessive changes of color by the application of the test-paper, for if the slightest increase of blueness in the wetted part is obtained, the solution is alkaline, and if a change *towards redness*, the solution is sufficiently acid, as a bright red indicates an excess.

It frequently happens that after the bath solution has been in use for some weeks or months, and has always worked well, it will suddenly change, and produce "foggy" pictures, although the test-paper shows it to contain the proper amount of acid. This sudden change has sorely puzzled many able photographers; but Mr. Horne has clearly shown that it arises from the *supersaturation* of the solution with iodide of silver,* aided by the evaporation of the solution which ensues in hot weather. To remedy this defect, add two ounces of distilled water to the bath solution, and filter, to remove the turbidness which ensues, then add one dram of nitrate of silver, and when it is thoroughly dissolved, filter again, to insure the solution being perfectly clear.

To Excite the Plate.—The plate, after being coated with iodised collodion, drained, and the ether allowed to evaporate, is ready to be excited; the time required for the ether to evaporate, and the film to "set," depends on the fluidity of the collodion, and also on the temperature. Until the amateur can judge from the appearance of the plate he should allow ten seconds to intervene between

* Iodide of silver is formed on the immersion of a plate, covered with iodised collodion, into the bath solution, giving rise to the yellow tint produced on the plate. This iodide of silver is partially soluble in the bath solution, which becomes, by long use, fully saturated, and in this condition is useless. The addition of the distilled water causes the iodide of silver to precipitate, and the nitrate of silver is added to bring the solution to its proper strength.

The bath solution after being in use some time becomes slightly weaker; the original strength may be restored by a small portion of nitrate of silver being added.

the ultimate draining and its immersion in the bath. If the plate is immersed too soon, transparent cracks will form in the film, on its lower edge, and if too much time intervenes, the film dries in parts, and develops unevenly.

Coating the plate is best effected with the aid of a good light, but all after operations must take place in a room from which every particle of white light is excluded; this is easily effected by covering up the windows of the operating room with three thicknesses of "yellow glazed calico," as light, after passing through this and other yellow mediums, although yielding sufficient illumination to serve our purpose, does not in the slightest degree have any chemical effect on the sensitive surface of the plate, whereas the slightest gleam of white light would cause it to whiten all over on applying the developing solution.

The bath, having been previously filled with bath solution, to within three-quarters of an inch of the top, and placed in the operating room, the plate, still held by one corner, is now laid, collodion side uppermost, so that it is in contact with the projecting slip on the glass dipper, and the dipper and plate is lowered into the bath with one steady motion, as any pause will cause a corresponding mark or line to develop itself on the picture in its after treatment.

The plate is now allowed to remain undisturbed in the bath for one minute, and is then to be partially drawn out of the fluid three or four times, and again immersed, until the greasy appearance of the surface, caused by the remaining ether of the collodion, is removed, and the solution flows off in one uniform sheet.

Two minutes' immersion in the bath is ample in warm weather, but from three to five minutes is required in winter.

The plate, having completely lost all appearance of greasiness on its collodion surface, is then removed from the dipper, by the finger and thumb applied to one corner, and allowed to drain, by being stood up nearly vertical on filtering-paper, in a dark corner of the operating room, where no white light can reach it, for ten seconds, to remove any excess of the bath solution; the solution adhering to the back of the plate is then removed by wiping (taking care not to touch the collodion side), and the plate is ready to be placed in the camera back.

The camera back is furnished with two flaps, one sliding in a groove, and the other opening, as a door, on hinges. All dust having been previously removed, the sliding flap is pushed down in its place, and the hinged flap opened; a plate-holder with silver wire corners, having an aperture adapted to the size of the plate, is laid into the camera back, so that the silver wire is next the sliding flap. The excited collodion plate is taken up from its position, where it was stood to drain, by being grasped by the thumb and fore-finger of the right hand, one to either of the longest sides: the camera back is held horizontal in the left hand, and the plate in-

serted, so that its four corners may rest on the wires, and that its collodion side may be next the sliding flap; the hinged flap is now shut down, and secured from coming open by the brass button being turned over it; in this state, the back containing the plate, may be taken out of the operating room without the possibility of light coming in contact with it, and it is now ready for exposure in the camera; but, previous to doing this, we must digress a little, and say a few words on the arrangement of the sitter, and on focusing.

Arrangement of the Sitter and Exposure in the Camera.—The sitter must be placed so that the figure is well illuminated, with one side of the face *slightly* in shade, and looking towards the north, if possible; two or three feet behind, a "background" must be set up composed of a blanket stretched over a frame, or, if this cannot be procured, hung, so as to be free from folds, over a large clothes-horse; a dark background must be used where the sitter has very light or gray hair; the hands and knees of the sitter must be so arranged as to be about the same distance as the face from the camera, to prevent those parts being out of focus or distorted by the lens.

The sitter should assume an easy natural position, free from constraint or a fixed look, and should, if possible, divest himself of the idea that his portrait is about to be taken, assuming, in look and position, an unstudied and natural appearance.

In general the full face makes but indifferent portraits; the most pleasing are with the head slightly turned on one side, termed three-quarter face, and the eye should be fixed steadily on some dark object.

The camera has now to be fixed on the camera stand, by means of the fixing screw, and placed in front of, and about four to eight feet from, the sitter, bearing in mind that the nearer the camera is placed to the sitter, the larger will be the image produced, and *vice versa*, so that if a small image is required, the distance between the camera and the sitter must be increased until the required size is obtained.

In order to be enabled to view the image of the sitter, which is formed on the ground glass when the cap of the lens is removed, a black linen or velvet cloth (termed a focusing cloth) is thrown over the back of the camera and head of the operator, so as to exclude all light except that which passes through the lens. By this means a brilliant inverted image of the sitter should be visible on the roughened surface of the focusing glass. If such is not the case, the sliding portion of the camera (if of the expanding form) is drawn out, until the image is nearly distinct; the rack and pinion head of the lens is now turned so as to move the lens in or out of the camera until the greatest possible sharpness of the image is obtained.

When this is the case, the cap is placed on the lens, the focusing screen removed from the camera, and the camera slide, containing the moist and sensitive collodion plate, is put into its place, taking es-

pecial care that the sliding shutter is towards the lens—a hint from the operator is necessary to insure the sitter keeping perfectly steady. The sliding shutter is now gently drawn up to its full extent; and when the vibration given to the camera by this action has ceased, the cap of the lens is removed, and the time of exposure noted by a seconds' watch. When the necessary amount of exposure has been given, the cap of the lens is replaced; the sliding shutter pushed down, and the camera slide removed from the camera and carried again into a dark room, there to receive the necessary application of a solution, to cause the developement of the impressed but quite invisible image: before, however, going into the necessary details of the developement, we must say a few words on the time of exposure necessary.

The time of exposure necessary to impress the latent image on the plate is dependent on so many varying influences, that it is impossible to lay down any exact rule for the guidance of the amateur. The focal length and aperture of the lens—the intensity of the light—the state of the collodion—and the amount of free acid in the bath, all act either together or singly to produce the most variable times of exposure, from two or three seconds to one minute; but, supposing the light to be of the ordinary intensity of a bright autumn day without direct sunshine on the sitter, the collodion iodised about twelve hours previously, and the bath but faintly acid, the time of exposure, with a portrait lens of four inch focus, the lenses of which have a clear aperture of one and five-eighths inch, will be about ten seconds; with a portrait lens of six inch focus, and two inches and three-eighths aperture, the exposure must be about nine seconds, whilst with a portrait combination of ten inch focus and three and a quarter inch aperture, the time of exposure will be about twelve seconds. If the sun is shining with the full vigor of summer, although the sitter is in the shade, the time may be reduced at least one-half; but the amateur is cautioned not to attempt the taking of instantaneous pictures, but to strive so to modify the light by screens, &c., that the exposure necessary may be about what is quoted above, as he may then expect to see the resultant pictures with a good contrast of lights and shades, and the middle tints clearly defined, whereas pictures taken with a less time of exposure generally possess the lights and shades well marked, but quite a deficiency of the middle tints; and as it is to these we look for softness and finish in the picture produced, we must cultivate their production to the greatest extent in our power.

TO DEVELOPE THE LATENT IMAGE.

Protosulphate of iron	-	-	-	-	2 drams.
Nitrate of barytes	-	-	-	-	1½ dram.
Glacial acetic acid	-	-	-	-	2 drams.
Alcohol	-	-	-	-	8 drams.
Rain, or distilled water	-	-	-	-	10 ounces.

Dissolve the two drams of protosulphate of iron in five ounces of water, to which add the two drams of acetic acid, and the three drams of alcohol; dissolve the one and a half dram of nitrate of barytes in five ounces of water; the crystals being completely dissolved, mix the two solutions together, when a dense white precipitate is formed, which, floating in the mixed solution, gives rise to an appearance of milkiness; allow the whole to remain undisturbed for two or three hours, during which time the precipitate will subside, and the upper clear fluid may be poured off, and filtered through filtering-paper for use.

This solution will keep good for a month, although it becomes a reddish color after being made a few days.

The camera slide containing the plate having been removed into the dark room, the plate is withdrawn from the slide, and placed, with the collodion side upwards, on a fixing stand, which must be previously made quite level, and then quickly covered with the developing solution,* which must be poured rapidly over the plate, so that the whole surface is completely covered.

Gently blow on the plate, so as to keep up a disturbance of the developing fluid, until the prominent whites of the picture are just visible, which, under ordinary circumstances *with the above developing solution*, takes at least half a minute. The plate is now taken up by the finger and thumb of the left hand, and the developing solution poured off, and then on again, five or six times, or until the middle shades of the picture are visible, although it must be remembered that the fainter shades are, at this stage, partially obscured by the iodide of silver.

When these shades show themselves, pour off all the developing fluid, replace the plate on the fixing stand, and pour gently over it at least half a pint of water, as it is necessary to remove every trace of the developing fluid. The plate is now ready for the next process, termed "fixing the image."

Fixing the Image.—This part of the process is for the purpose of removing from the plate the unaltered iodide of silver, which if allowed to remain, would be liable to alter by exposure to light, and much obscure the details of the picture.

FIXING SOLUTION.

Cyanide of potassium	-	-	-	20 grains.
Water (rain or filtered),	-	-	-	8 ounces.

Dissolve the cyanide of potassium in the water and keep closely stoppered for use.

The plate, having been thoroughly washed so as to remove every trace of the developing fluid, is placed on the fixing stand, and a

* The quantity of solution necessary to cover a plate five inches by four inches is three drams.

sufficiency of the fixing solution poured on to cover it; this is allowed to remain on until the yellow opalescent color of the film disappears, which takes place in from one to two minutes, and in order to facilitate the operation, the plate may be gently blown on so as to keep the solution agitated.

When the yellow color disappears, the plate may be tilted and a stream of water gently poured on, so as to remove every trace of the fixing solution, which if allowed to remain would cause the picture, sooner or later, to disappear; when the operator is satisfied that none of this solution remains, the plate may be drained and then dried, either over a spirit-lamp or before a fire, and is then ready to receive the last operation of "varnishing" and "backing up," termed—

Finishing the Positive Picture.—The plate having been thoroughly dried and made moderately warm over a spirit-lamp or near a fire, is taken between the finger and thumb of the left hand and crystal varnish poured over the collodion side, and this drained off exactly in the same manner as described for the application of the iodised collodion, so that a thin uniform stratum may remain; after being drained, the plate has again to be warmed, so as to facilitate the drying of the varnish and to prevent its becoming milky instead of transparent. When this coating is thoroughly dry the plate has again to be warmed, and a coating of BLACK JET poured over its uncovered surface (*not on the collodion side*), and this drained off and stood up on its edge to dry, which will take from two to twenty-four hours. When the black varnish is thoroughly dry, the picture is ready to be mounted, either in a morocco case or morocco frame, in which case, the collodion side being upwards, requires to be protected by an outer covering of glass, which is prevented from resting on the picture by the interposition of a gilt mat with an appropriate opening to suit the picture; or the picture may be mounted in a passe partout, when no extra glass is required, as in this case, the glass of the passe partout serves instead. The picture is inserted by making an opening at the back.

The only objection to this plan of finishing is, that the sides of the portrait are reversed—that is, a blemish on the right cheek appears as though it were on the left. If this is considered objectionable, the black varnish may be applied *on the collodion side*, after the application of the crystal varnish, but not until the plate has become quite cold; as, if applied when the plate is warm, the black varnish is very liable to permeate the crystal varnish and give a brown tone to the whites of the picture.

The appearance of the picture when finished serves to indicate whether the bath is in good condition, and whether the proper time of exposure was given in the camera.

If the features present a dull, heavy appearance, without any, or but few of the middle tints or dark shades of the drapery showing

themselves, the cause is either a too acid bath, or from the use of collodion that has been too long iodised, or too short an exposure in the camera. If the dark shades of the pictures show themselves with too much effect, being nearly as visible and prominent as the high lights, and the whole has an appearance as though seen through an opaque film, termed "fogging," it arises from one of the following causes :

- The absence of acid in the bath ;
- Over-exposure in the camera ;
- An admission of white light to the plate after being excited ; or,
- A too long application of the developing fluid.

As over-exposure in the camera is most likely to give rise to this defect termed "fogging," it is recommended to prepare another plate, and give it only one half the exposure. Should this prove ineffective, and the defect still exist as prominent as before, it must be remedied by guarding against the other causes which may give rise to it. The time necessary to expose a plate in the camera, to produce the maximum effect of brilliancy in the picture, is one requiring some degree of tact and knowledge, so as to suit the time to the ever-changing intensity of light ; but the process here detailed admits of considerable deviation from the correct time of exposure, so that the amateur need have no fear about his ultimate success, after, perhaps, a few failures ; as, if *over-exposed*, the picture develops rapidly ; whilst, if *under-exposed*, the action of the developing fluid being slow, and but little liable to over-develop on the high lights, admits a continued application until the middle tints are also visible.

COLLODION PROCESS FOR NEGATIVES.

Negative Collodion.—This preparation is made in the following manner : Half an ounce of dried nitrate of potass, in fine powder, is to be mixed with three-fourths of an ounce of ordinary strong sulphuric acid, of specific gravity about 1·850, in a porcelain capsule, with a glass rod, and half a dram of clean dry cotton is then added as quickly as possible, and stirred about in the mixture for about five minutes ; when removed, it is to be carefully and thoroughly washed with water, and dried by exposure to a warm atmosphere. Ten grains of the gun-cotton thus obtained are dissolved in half an ounce of sulphuric ether, to which is added one dram of alcohol. Five grains of iodide of potassium or of iodide of ammonium are now dissolved in the smallest quantity of alcohol, and added to the collodion, together with about three ounces of sulphuric ether, so as to enable it freely to flow over a glass plate.

A few grains of iodide of silver dissolved in the iodide of potassium increase its sensibility, in which case the preparation must not be used until it has become clear, by allowing the superfluous

iodide to settle, or a multitude of black specks will be formed on the plate.

There are six operations in obtaining a negative collodion picture, viz.: Cleaning, coating, and exciting the plate, reception and development of image, and, finally, fixing and preserving the same from injury.

Cleaning the Plate.—This is done with the same care, and by the same means, as described at page 63 for collodion positives.

Coating the Plate.—The method fully described at page 64 for positive collodion must be followed, of course using the negative collodion for the purpose, of which the method of making is described above.

Exciting the Plate, and Exposure in the Camera.—For this purpose is required a dipping-trough, which is to be filled with a solution of nitrate of silver, or bath composed as follows:

Nitrate of silver in crystals	-	-	-	-	6 drams.
Iodide of potassium	-	-	-	-	3 grains.
Distilled water	-	-	-	-	12 ounces.
Alcohol	-	-	-	-	2 drams.

Dissolve the six drams of nitrate of silver in one ounce and a half of the distilled water, and the three grains of iodide of potassium in one dram of distilled water; mix the two solutions, and shake well together until the precipitate, which is first thrown down, is redissolved; when this takes place, add the remaining ten ounces and a half of distilled water and the two drams of alcohol. On the addition of the water a turbidness ensues, which must be removed by the solution being very carefully filtered through filtering-paper; and the filtered liquid should be clear and transparent, free from any deposit or floating particles.

In order to ascertain if the solution, thus prepared, possesses the necessary amount of free acid without superabundance, moisten a fragment of test-paper with a drop of the solution, and observe the effect of this application on the color of the paper.* If the color remains unchanged, the solution is neutral; if it turns blue, it is alkaline, and in either case would produce hazy pictures (termed "fogging"). To remedy this defect, add acetic acid, diluted with ten times its bulk of water, drop by drop, until the solution, when applied to the litmus-paper, changes its violet color to a reddish tint. Should an excess of acetic acid be added, or should the solution, when first tried, change the color of the test-paper to a decided red tint, the bath is too acid (which would render the collodion very slow in action). This defect is removed by adding ammonia, diluted with ten times its bulk of water, drop by drop, until the solution changes the test-paper to a reddish violet tint, which

* See mode of observing the color of test-paper at page 65.

indicates just that amount of excess of free acid that serves to insure success in the production of negative pictures, and it is advisable frequently to test the nitrate of silver bath in order to remove either an alkaline or a too decided acid effect.

The glass plate having been coated with iodised collodion, is laid on the dipper, and *immersed steadily and without hesitation* in the dipping-trough, for if a pause should be made at any part, a line is sure to be formed, which will print in a subsequent part of the process.

The plate being immersed, must be kept there a sufficient time for the liquid to act freely upon the surface, particularly if a negative picture is to be obtained. As a general rule, it will take from two to four minutes, varying with temperature and make of the collodion. In very cold weather, or indeed any thing below 50° Fahrenheit, the bath should be placed in a warm situation, or a proper decomposition is not obtained under a very long time. Above 60° the plate will be almost certain to have obtained its maximum of sensibility by two minutes' immersion; but as the plate cannot injure by remaining a longer time in the bath, it is better, in all cases when a negative picture is required, to give time for the whole of the iodide in the collodion to be thoroughly acted on by the nitrate of the bath.

To facilitate the action, let the temperature be what it may, the plate must be lifted out of the liquid two or three times, which also assists in getting rid of the ether from its surface, for without this is thoroughly done, a uniform coating cannot be obtained; but on no account should it be removed until the plate has been immersed about half a minute, or marks are apt to be produced.

Having obtained the desired coating, the plate is then extremely sensitive to white light, and therefore we presume the operator has taken every precaution to exclude ordinary daylight.

The best way of doing this is to hang over the window two or three thicknesses of yellow calico, by which means the light which passes through will be amply sufficient for manipulation, and at the same time produce no injury to the sensitive plate.

If the foregoing plan cannot be followed, the room must be closed against any portion of daylight, and a candle alone employed, *placed at a distance* from the operator, to give the requisite light.

The plate thus rendered sensitive, must then be lifted from the solution, and held over the trough, that as much liquid as possible may drain off previously to being placed in the camera-frame, and the more effectually this is done the better, or the action in the camera will not be equal over the whole surface; at the same time, it must *not be allowed to dry,** but, in short, to obtain its

* If the plate is allowed to become dry before exposing it in the camera, it loses its sensitiveness to the action of light. It is therefore imperative that the

full maximum of sensibility, it should be damp without superfluous moisture.

The question is often asked—How soon, after coating the plate with collodio-iodide, should it be immersed in the nitrate bath? Now this is a difficult question to answer. We have said the time of *immersion* is dependent upon temperature and make of collodion, so likewise must we be governed as to time *before immersion*. To make collodio-iodide, or xylo-iodide—for, chemically speaking, there is no difference in the two—it is necessary that the ether should contain a certain quantity of alcohol, or the different articles are not soluble; therefore, if we take a fresh bottle, and coat the plate from this while it contains its full dose of ether, and with the thermometer ranging between 60° and 70°, the evaporation of this article will be very rapid, and, consequently, a tough film soon formed; but if, on the other hand, we are using an article which has been in use some time, and many plates, perhaps, coated, the proportion of alcohol will be much greater, and, not being of so volatile a nature, will necessarily take a longer time to acquire the requisite firmness for immersion. Hence it is evident we must be guided by circumstances. If, for instance, after coating a plate, we find, on immersion, it does not color freely, we have then reason to suppose the plate has not been immersed sufficiently quick; but if, on the other hand, we find the film very tender, and, upon drying, it cracks, then we have reason to know that plates prepared from that bottle must not be immersed quite so soon. The larger the proportion of alcohol, the more tender the film, but the more sensitive will be the plate, and the quicker and more even will be the action of the bath.

The next question also often asked is—How long must be the exposure in the camera?—a question more difficult to answer than the last, without knowing something of the working of the lens and intensity of light. Practice alone can determine, combined with close observation of those parts which should be the shadows of a picture. If, for instance, in developing, we find those parts less exposed to the light than others develop immediately the solution is applied, then we have every reason to suppose the exposure has been too long; but if, on the contrary, they develop very slowly, we have proof that the time allowed has not been sufficient to produce the necessary amount of action. In a good picture we should see first the whites of a dress appear, then the forehead, after which we shall find, if the light has been pretty equally diffused, the whole of the face, and then the dress.

exposure takes place within a few minutes after removing the plate from the bath. This renders collodion of very little value for taking views, as in such situations we cannot always command the use of a dark room. For these purposes we must employ either the Calotype, waxed-paper process, or the new collodio-albumen process.

Much will, of course, depend upon the arrangement of light, for if the sitter is not placed in a good aspect, by which is meant a good diffused light, the prominent parts only will come out; or, to produce the necessary amount of action to obtain the others, the high lights are so overdone that the picture prints raw and cold.

Can I produce portraits at my drawing-room window? This is another common question, and the reply must necessarily be, Yea, if you have sufficient light, and can so place your camera that the sitter may be pretty equally illuminated, and not one-half receiving nearly all the light; if it does, one side may be amply done and the other scarcely visible.

In cases of this description the necessary effect may often be produced by placing a white screen so as to reflect a portion of light upon the darkened side; but, upon the whole, a light of this character is better adapted for producing positive than negative pictures upon glass.

We must now suppose the plate to have received its necessary impress in the camera, and proceed to—

The Development of the Image.—To effect this it must be taken into the room where prepared, and, with care, removed from the slide to the levelling stand. It will be well also to caution the operator respecting the removal of the plate. Glass, as before observed, is a bad conductor of heat; therefore if in taking it out, we allow it to rest on the fingers at any one spot too long, that portion will be warmed through to the face, and on applying the developing solution the action will be more energetic at those parts than the others, and consequently destroy the evenness of the picture. We should, therefore, handle the plate with care, more as if it already possessed too much heat to be comfortable to the fingers, and get it on the levelling stand as soon as possible.

Having then got it there, we must next cover the face with the developing solution.

This should be made as follows:

Pyrogallie acid	-	-	-	-	-	5 grains.
Distilled water	-	-	-	-	-	5 ounces.
Glacial acetic acid	-	-	-	-	-	1 dram.
Alcohol	-	-	-	-	-	half a dram.

Mix and thoroughly filter.

Now, in developing a plate, the quantity of liquid taken must be in proportion to its size. A plate measuring five inches by four will require half an ounce; less may be used, but it is at the risk of stains; therefore, we would recommend, that half an ounce of the above be measured out into a *perfectly clean glass measure*, and to this add from eight to twelve drops of a solution of nitrate of silver, containing 50 grains to the ounce of water.

Pour this quickly over the surface, taking care not to hold the measure too high, and *not to pour all at one spot*, but, having taken the measure properly in the fingers, begin at one end, and carry the hand forward; immediately blow gently upon the face of the plate, which has the effect, not only of diffusing it over the surface, but causing the solution to combine more equally with the damp surface of the plate; it also has the effect of keeping in motion any deposit that may form, which, if allowed to settle, causes the picture to come out mottled. A piece of white paper may now be held under the plate, to observe the development of the picture: if the light of the room is adapted for viewing it in this manner, well; if not, a light must be held below; but in either case arrangements should be made to view the plate easily whilst under this operation, a successful result depending so much upon obtaining sufficient development without carrying it too far.

In some instances it is better not to mix the nitrate of silver solution with the pyrogallic solution until after the latter has been poured over the plate, but in no case must it be mixed *on the plate*; the solution must be poured off into the measure and the nitrate added. In this way we can judge better of the intensity of the picture, for when the solution is off, the plate can be held up to the light and the image viewed through. Care should be taken that the nitrate of silver solution is free from deposit.

The author has also found a weak developing solution, as given above, far more successful in obtaining gradation of tone than when stronger, for, in the latter case, the action will be very energetic on those parts reflecting the most light, and, consequently, become overdone before other portions, such as dress, &c., have become sufficiently visible. The addition of an extra portion of nitrate of silver will be found to improve the tone, but this may be effected also without adding it to the pyrogallic solution; and, in many instances, it will be found a better plan to re-dip the plate in the bath, after exposure in camera, particularly if any considerable time has elapsed between the excitement of the plate and development of the picture, for the plate having dried unequally, does not allow the same uniform development as when well moistened over the surface.

As soon as the necessary development has been obtained, the liquid must be poured off, and the surface washed with a little water, which is easily done, by holding the plate over a dish and pouring water on it, taking care, both in this and a subsequent part of the process, to hold the plate horizontally, and not vertically, so as to prevent the coating being torn by the force and weight of the water.

This being done we arrive at the—

Fixing of the Image—Which is simply the removal of yellow iodide of silver from the surface of the plate, and is effected by pouring over it, after the water, a solution of hyposulphite of soda,

made of the strength of four ounces to a pint of water. At this point daylight may be admitted into the room, and indeed we cannot judge well of its removal without it. We then see the iodide gradually dissolve away, and the different parts left more or less transparent according to the action of light upon them.

It then only remains to thoroughly wash away every trace of hyposulphite, for should any of this salt be left, it gradually destroys the picture. The plate should, therefore, either be immersed with great care, in a vessel of clean water, or, what is better, water poured gently and carefully over the surface.

After this it must be stood up to dry or held before a fire.

It may be as well to state, that any clean filtered or rain water will answer for washing, distilled being only required for the solutions of nitrate of silver, &c.

Having by the foregoing means, obtained and fixed a negative photographic image on glass, which is capable of producing positives upon paper by the printing process described at page 85; it is well, previous to obtaining these, to render the tender film of collodion less liable to injury.

This is best accomplished by—

Varnishing the Plate.—There are two kinds of varnishes which may be used for this purpose—the spirit and the chloroform. Some amount of care is necessary in the use of the spirit varnish, for if it is poured on the plate cold the gums chill and the picture is rendered opaque; therefore, the best plan of proceeding is as follows:

Hold the back of the plate to a fire until warm through, care being taken not to make it too hot, or the varnish will not run properly; then pour the varnish on in the same manner as the collodion, and return the superfluous portion to the bottle. Hold the plate again to the fire to drive off the spirit, when a beautiful surface will be obtained, making it difficult, at first sight, to judge which side has been varnished.

There is also another kind of varnish which has been recommended by Dr. Dymond, viz., gum amber, dissolved in chloroform. This is used by many photographers, as it can be put on cold, and dries directly upon evaporation of the chloroform, which is its only advantage over the spirit varnish, and is necessarily much more expensive.

COLLODIO-ALBUMEN PROCESS.

This is a process, invented by Dr. Taupenot, for obtaining negatives on glass, which bids fair to outrival all others, being easy of manipulation, and giving results of the most exquisite minutiae and beauty. Glass plates, when prepared and excited by this process, may be kept at least a fortnight before being developed, and these plates when exposed in the frame may be developed immediately, or kept for days before commencing this operation. Indeed it is

quite possible to prepare and excite a number of plates before leaving home to go on a tour of twelve or fourteen days; to expose the plates at any time or place during the journey, and bring them home to be developed.

The manipulation may be said to consist of nine distinct operations:

1. Cleaning the plate.
2. Coating with iodised collodion.
3. Exciting the collodion film.
4. Coating with albumen.
5. Exciting the albumen coating.
6. Exposure in the camera.
7. Developing the image.
8. Fixing the image.
9. Varnishing the plate.

Before describing these operations, I propose to give clear directions for preparing the necessary solutions, merely premising that, where I have deviated from the inventor's plan, it has been after performing careful experiments to test the merits of the two modes of proceeding.

The necessary solutions for this process are—

Collodion bath solution.	Albumen bath solution.
Iodised collodion.	Pyrogallic solution.
Iodised albumen.	Silver developing solution.
Fixing solution.	

COLLODION BATH SOLUTION.

Nitrate of silver in crystals	-	-	-	-	1 ounce.
Iodide of potassium	-	-	-	-	2 grains.
Distilled water	-	-	-	-	16 ounces.
Alcohol	-	-	-	-	2 drams.

Dissolve the ounce of nitrate of silver in two ounces of the distilled water, and the two grains of iodide of potassium in one dram of distilled water; mix the two solutions, and shake well together until the precipitate, which is first thrown down, is redissolved. When this takes place, add the remaining fourteen ounces of distilled water, and the two drams of alcohol. On the addition of the water, a turbidness ensues, which must be removed by the solution being very carefully filtered through filtering-paper; and the filtered liquid should be clear and transparent, free from any deposit or floating particles, and must possess a slightly acid reaction to test-paper.

In order to ascertain if the solution thus prepared possesses the

necessary amount of free acid without superabundance, proceed to test and to correct it, if necessary.

Iodised Collodion.—The collodion necessary to be used in this process must be one yielding good *negative* pictures. This is supplied either ready iodised, or the collodion and iodising in separate bottles. As this collodion becomes less sensitive after being iodised a fortnight, it is advisable to iodise no more than will be used in that time; therefore, obtain the collodion and the iodising solution separate, as the mode of iodising this collodion is very simple. Half an ounce of the iodising solution is mixed with one ounce and a half of collodion, and the mixture allowed to settle twelve hours before being used; and it is even advisable to pour off the clear solution into a perfectly clean bottle, in order to get rid of any insoluble matter which may fall to the bottom.

IODISED ALBUMEN.

White of egg (free from yolk)	-	-	-	10 ounces.
Honey	-	-	-	1 ounce.
Iodide of calcium	-	-	-	40 grains.
Yeast	-	-	-	1 tablespoonful.

Mix these together in a tall glass jar, or wide-mouthed bottle of at least one pint capacity; tie a piece of paper, pierced with small holes, over the top to keep out dust; then place the whole near a fire or other warm situation, where the temperature is not lower than seventy degrees, or higher than ninety degrees. In a few hours fermentation commences, which is evident by the formation of bubbles of gas rising through the liquid. This action continues for five or six days; when it ceases, pour the whole on a paper-filter contained in a funnel, underneath which must be placed a bottle to receive the liquid as it passes through. The fluid being of a viscid nature, filters slowly, generally occupying twelve hours.

The filtered liquid is the "iodised albumen," which is said by Dr. Taupenot to keep good for years. It must be carefully preserved from dust, or contact with any substance, as the success of the picture depends materially on the condition of this albumen.

ALBUMEN BATH SOLUTION.

Nitrate of silver	-	-	-	-	1½ ounce.
Acetic acid (glacial)	-	-	-	-	1 ounce.
Distilled water	-	-	-	-	16 ounces.
Animal charcoal	-	-	-	-	2 drams.

Dissolve the nitrate of silver in the distilled water, then add the acetic acid and animal charcoal, and keep in a closely-stoppered bottle for use.

PYROGALLIC SOLUTION.

Pyrogallie acid	-	-	-	-	15 grains.
Glacial acetic acid	-	-	-	-	2 drams.
Alcohol	-	-	-	-	2 drams.
Distilled water	-	-	-	-	7 ounces.

Dissolve the pyrogallic acid in the distilled water, and then add the acetic acid and alcohol.

SILVER DEVELOPING SOLUTION.

Nitrate of silver	-	-	-	-	-	-	1 dram.
Acetic acid	-	-	-	-	-	-	2 drams.
Distilled water	-	-	-	-	-	-	7 ounces.

Dissolve the nitrate of silver in the distilled water, and then add the acetic acid.

FIXING SOLUTION.

Hypo-sulphite of soda	-	-	-	-	-	-	2 ounces.
Water	-	-	-	-	-	-	1 pint.

Dissolve.

Cleaning the Plate.—The directions already given as to cleaning plates, refer with equal force to this process, and, therefore, need not be repeated; merely premising that extra care must be observed to remove every impurity, as cleanliness in photography is an absolute necessity.

In order to hold large plates whilst being cleaned, the "screw plate-holder" is exceedingly useful. This is made in three sizes, and adapts itself to all size plates.

The small size is useful for plates up to seven inches by six inches.

The second size is for plates up to ten inches by eight inches.

And the third size for plates up to fourteen inches by ten inches.

Coating with Iodised Collodion.—The plate having been thoroughly cleaned, and received its final polish by the use of prepared chamois leather, it is coated with negative collodion, which has been iodised at least twelve hours, and allowed to settle.

*Exciting the Collodion Film.**—After the ether has evaporated, and the surface of the collodion appears set, the plate must be laid, collodion side upwards, on a glass dipper, and plunged, with *one downward movement* into a bath filled to within an inch of the top with collodion bath solution, made as before described, which must be carefully filtered through filtering-paper before being used. After the plate has been allowed to remain in the bath one minute, it is lifted out three or four times in order to facilitate the removal of the *oily appearance* which the plate now presents. When the surface appears wetted uniformly, on being drawn out of the solution the plate is removed from the dipper, and the excess of solution drained off, and is then placed, collodion side upwards, on a fixing stand, and distilled or filtered rain-water poured over the surface, so as to remove *as much as possible of the bath solution* from the sur-

* This and subsequent operations (except exposure in the camera) must be performed in a dark room, as directed for "Collodion positives on glass."

face. The plate is now removed from the fixing stand, the back well washed with water, and then placed nearly upright on blotting-paper, with the face against the wall for *one minute*, to drain.

Coating with Albumen.—Having allowed the plate to drain one minute, place it again on a levelling stand, with the film upwards, and pour over it as much of the iodised albumen (previously filtered, if necessary) as the plate will hold, from a glass measure containing not more than enough of the albumen to coat two plates; pour off the excess into the measure and again cover the plate with albumen three separate times; ultimately, drain off as much as possible of the excess of albumen, and place the plate nearly upright against the wall, with the coated side inwards, to dry, which takes place, in an ordinary temperature, in about one hour.

In coating with albumen, the presence of air-bubbles or dust must be guarded against. The former can easily be done by taking care, in pouring the albumen into the measure and on the plate, not to pour so as to generate air-bubbles in the liquid. But should any be detected, hold the plate horizontally and give it another coating of albumen, then incline the plate so that the bulk of the liquid shall pass over and carry off the bubbles with the running stream. Dust on the plate must be prevented by operating in a room as free from this photographic enemy as possible.

In order to render the coating of albumen as uniform as possible, the plate must stand to dry on two or three layers of filtering-paper, and the upper surface must touch the wall at *one point only*, and not be allowed to rest against it along its entire upper edge.

When the albumen coating is *thoroughly dry* (and not till then), the plate is ready to be excited, but if more have been prepared than are likely to be used for taking pictures on during the next ten days or fortnight, they may be stowed away in a plate box, ready to receive the sensitive coating at any time. The author's experience has led him to believe that these albumenised plates will keep good any length of time, as plates which had been coated a month, when excited, exposed, and developed, appeared to possess all the properties of recently prepared plates.

Exciting the Albumen Coating.—Prior to the plates being excited they must be *thoroughly dry* and free from any particles of loose dust on the surface, back, or edge. Sufficient of the albumen bath solution must be filtered through filtering-paper to fill a dipping bath of the required size, so that the plate can be immersed in it.

The careful filtering of the fluid is very necessary in order to free it from any floating particles, and to separate the animal charcoal.

The plate is now taken and laid, albumen side upwards, on the dipper, and then lowered into the bath with *one steady downward movement*, where it is allowed to remain *one minute*; it is then taken out, the excess of liquid drained off, and placed on the fixing

stand, with the albumen surface uppermost, and a stream of water poured over it for at least one minute, so as to remove every particle of the bath solution. This complete washing is very necessary, in order to prevent stains in the after development, which invariably takes place around the edges, if not thoroughly washed. The plate, having been thoroughly washed, is leaned against a wall to dry, or if required for immediate exposure, may be dried on a plate of heated metal or a foot-warmer, *but in no case must the exposure in the camera take place until the surface is thoroughly dry.*

*Exposure in the Camera.**—As has been before stated, this operation may take place immediately the plate is thoroughly dry after being excited, or a fortnight may intervene between the exciting and exposure, provided the plate is kept very carefully excluded from light and any chemical or sulphurous vapors, in a plate box adapted for that purpose, with the sensitive surface towards the back of the box. When the exposure is about to take place, or at any time previously, the camera backs may each have a plate placed in them ready for exposure; to do this, the camera back must be taken into the operating room and the door closed, so as to exclude all white light. The hinged flap of the camera back is opened, and the prepared plate laid, with its sensitive surface *downwards*, or next the sliding flap, so that its corners may rest on the silver wire corners of the plate frame previously placed within the camera back ready to receive it. The hinged flap is now closed and kept from opening by turning the flap button over it; the sliding flap is examined to see that it is pushed closely down so as to guard any access of light, and it is then ready to be placed in the camera, and may be taken into the open air with impunity. Should the exposure not take place immediately, or, should the camera back have to be carried any distance, it is advisable either to wrap it up in a black cloth, or secure the flaps from the chance of coming open, during transit, by a stout string being tied around the back.

The focusing is conducted in the same way as already given, and the cap replaced on the lens; the focusing glass is now removed and the camera back fitted into the same aperture, *with the sliding flap next the lens.*—The sliding flap is pulled up to its fullest extent, placing the hand on the camera back to prevent it rising out of the camera with this action. The cap of the lens is then removed, so that the light may be admitted into the camera, and to fall on the sensitive surface of the plate. After the necessary time of exposure has taken place, the cap is replaced on the lens, the sliding flap is pushed down, and the camera back withdrawn from

* Remarks as to the selection of the view, &c., are not given, as this can best be effected by the individual taste of the operator, but care must be taken that direct rays from the sun shall not fall on the lens or enter the camera during the exposure of a plate.

the camera; the plate can then be taken into the operating room to be developed, or this operation may be deferred for days or even a week or more if convenient. The time of exposure in the camera varies according to the intensity of the light and the aperture and focal length of the lens; therefore, to give the exact time of exposure would be impossible; still it may assist the amateur if I give the time required in summer with full sunshine, and merely state that this time may be increased to double in winter or dull weather.

In the ordinary sunshine of a summer's day the time of exposure will be—

30 seconds with a lens of 4-inch focus and $\frac{1}{4}$ -inch stop.

21 seconds with a lens of 4-inch focus and $\frac{3}{8}$ -inch stop.

5 seconds with a lens of 4-inch focus and $1\frac{1}{4}$ -inch aperture, with no stop.

$1\frac{1}{4}$ minute with a lens of 6-inch focus and $\frac{1}{4}$ -inch stop.

$4\frac{1}{2}$ seconds with a lens of 6-inch focus and $2\frac{1}{4}$ -inch aperture, with no stop.

2 minutes with a lens of 8-inch focus and $\frac{1}{4}$ -inch stop.

$1\frac{1}{4}$ minute with a lens of 8-inch focus and $\frac{3}{8}$ -inch stop.

$3\frac{1}{4}$ minutes with a lens of 10-inch focus and $\frac{1}{4}$ -inch stop.

2 minutes with a lens of 10-inch focus and $\frac{3}{8}$ -inch stop.

5 seconds with a lens of 10-inch focus, $3\frac{1}{4}$ -inch aperture, with no stop.

$6\frac{1}{4}$ minutes with a lens of 14-inch focus and $\frac{1}{4}$ -inch stop.

4 minutes with a lens of 14-inch focus and $\frac{3}{8}$ -inch stop.

$2\frac{1}{4}$ minutes with a lens of 14-inch focus and $\frac{1}{2}$ -inch stop.

$8\frac{1}{4}$ minutes with a lens of 16-inch focus and $\frac{1}{4}$ -inch stop.

$5\frac{1}{4}$ minutes with a lens of 16-inch focus and $\frac{3}{8}$ -inch stop.

$2\frac{1}{2}$ minutes with a lens of 16-inch focus and $\frac{1}{2}$ -inch stop.

Developing the Image.—The camera back is taken into the operating room, from which all white light is carefully excluded, the plate removed from the camera back, and laid, albumen side upwards, on the fixing stand; as much distilled water is now poured on it as the surface will hold, taking care that *every part of the sensitive surface is covered with the liquid*; allow the water to remain on the surface for one minute, then pour off and drain slightly; replace the plate on the stand, and pour over the surface, so as thoroughly to cover every part, the pyrogallic solution (made as described, and *carefully filtered* just before being used); allow this to remain on the plate for one minute, then drain off into a perfectly clean measure, and add to it an equal bulk of silver developing solution; *mix these thoroughly* together with a glass rod, and then pour the mixed liquids over the plate; allow them to rest until the picture begins to appear, which generally takes about from three to five minutes; then pour off and on repeatedly, until the developing fluid becomes opaque, which then contains floating particles, and

these, if allowed to do so, would settle on the plate, to the injury of the picture; but this may be prevented by brushing the surface with a camel-hair brush frequently during the development. When this opacity of the developing fluid takes place, drain all the fluid off the plate, and thoroughly wash with water; then mix another quantity of pyrogallic and silver developing solution in the same proportions as before, and pour this on and off the plate as before, until the picture appears sufficiently intense, and the middle shades well brought out; when this takes place, drain off, and wash with water, so as to clean the surface thoroughly, and the plate is then ready for the next step, "fixing the image."

Should the picture begin to develop in less than three minutes after the application of the mixed developing fluids, thoroughly drain the plate, and wash well with water, then continue the development with a solution of three parts pyrogallic solution, and one part silver developing solution; but should the picture not begin to appear in five minutes, the addition of half a dram of the albumen bath solution to each ounce of mixed developing solution will be necessary in order to obtain the middle shades, and the required intensity.

It may be stated, as a guide, that the best negatives which the author has produced occupied from ten to twelve minutes in developing.

Fixing the Image.—The plate having been thoroughly freed from the developing fluid by careful washing, is now placed on the fixing-stand, and the surface covered by the fixing solution being poured over it. In a few seconds the yellow opalescent color of the film will begin to disappear, and its complete removal may be hastened by blowing gently on the plate, so as to disturb the fluid.

When every particle of yellowness has disappeared, the fixing solution is drained off, and the surface *thoroughly washed*, and it is then leaned against the wall to drain and dry.

Varnishing the Plate.—The plate being thoroughly dry, is ready to receive a coating of transparent varnish, in order to protect the albumen surface from injury during the printing process. To do this effectually, the plate must be held before a fire, or over a lamp, until it is slightly warm all over; then pour over its surface some mastic varnish, in the same manner as collodion is applied; allow the superfluous varnish to drain back into the bottle; hold the plate again before the fire until the whole of the spirit is evaporated; and, when cold, the plate is ready to be printed from, so as to produce any number of positive pictures on paper, by the process described.

PRINTING PROCESS.

The paper for printing positives from glass or paper negatives is usually thicker than that employed for taking negatives on by the

calotype, or waxed-paper process, and is designated "positive" paper. Various kinds are used.

The kind of paper having been determined on, the sheets are examined one by one, in order to reject those having black spots or minute holes, and a pencil mark is made in each corner of the sheet on its *smoothest* side, in order that this side may be easily recognised in the after processes.

In some kinds of paper the smoothest side is easily recognised; in others, having a "water-mark," it may be known by holding the sheet up to the light, so that the maker's name may be read (the letters not reversed), when the side *nearest* the operator is the smoothest. There are other kinds in which the two surfaces are rendered apparently alike by the pressure used in its manufacture, and in which no "water-mark" exists. To recognise the required side in this case is more difficult, but still it is easily effected if one of the corners of each sheet is soaked in water for two minutes, and then dried. As the smoothness given by the pressure is, by this plan, removed, the smoothest side is instantly determined.

The paper has now to be "salted," which consists in applying to it a solution of muriate of ammonia, which can be done by either brushing or immersion. But it must be carefully noticed that the solution for immersion is not strong enough for being brushed on.

Salting Paper by Immersion.—In order to salt paper by immersion, take a porcelain pan and fill it to a depth of half an inch with the following solution :

Muriate of ammonia	-	-	-	-	-	20 grains.
Water	-	-	-	-	-	10 ounces.

Dissolve.

Into this solution carefully immerse one dozen sheets of paper, sheet by sheet, taking care to avoid air-bubbles; after soaking five minutes, turn over the whole mass so as to commence at the sheet first immersed, and hang them one by one up to dry, on a line stretched across a room. The most convenient accessories for this purpose are "photographic pins." The short limb of one of these pins is passed through one corner of each sheet, and the long limb is hooked over the line. After the sheet has drained a few minutes, a piece of filtering-paper, about one inch square, is applied to the lowest corner, to which it will adhere, and much facilitate the removal of the superfluous moisture.

Paper thus prepared will keep good any length of time.

Salting Paper by Brushing.—Salting paper by brushing is prepared by the use of the following :

Muriate of ammonia	-	-	-	-	-	20 grains.
Water	-	-	-	-	-	4 ounces.

Dissolve.

Pin the sheet of paper, with the marked side uppermost, upon a "preparing board," and brush the above solution carefully over the whole surface with a camel-hair brush, applying the solution by longitudinal and then transverse strokes of the brush, so as to cover every part, and when the paper appears thoroughly wetted, and will imbibe no more, drain off any superfluous moisture, and hang up to dry, as above described. Paper thus prepared also keeps any length of time.

We will now suppose the operator has prepared a quantity of salted paper by one or other of the above methods, and wishes to obtain a positive print from either a glass or paper negative.

Exciting the Salted Paper.—A sheet of the salted paper is first to be "excited," which may be done by the following solution :

Nitrate of silver	-	-	-	-	-	1 dram.
Distilled water	-	-	-	-	-	1 ounce.

Dissolve.

To apply this solution, pin a piece of the salted paper upon a clean board, and with a soft camel-hair brush coat the surface thoroughly with the above nitrate of silver solution. Care must be taken that the surface be thoroughly wetted all over alike, and this can only be done by applying the solution until the paper can imbibe no more, or the picture will be certain to present streaks. A little practice will enable any one to apply the solution thoroughly to the paper, and yet have none to run off.

This being done, they must be dried in the dark, or, what is better, at once by the fire. Papers prepared in this manner are not like those excited for the camera, where every trace of white light must be excluded; these, on the contrary, may be prepared in any ordinary room *away from the window*, taking the precaution, as soon as they are dry, to put them in a portfolio.

Another plan of "exciting" the salted paper is by the employment of the ammoniacal nitrate of silver, as first suggested by Mr. Alfred Smee. This solution is prepared in the following manner: In a two-ounce stoppered bottle place two drams of nitrate of silver, and pour over it one ounce of distilled water. When the crystals are dissolved, ammonia is added, a few drops at a time, and the bottle well shaken after each addition. The whole first becomes of a dark-brown color, from a precipitation of oxide of silver, but immediately the necessary quantity of ammonia is added, the solution becomes perfectly clear. A few crystals of nitrate of silver are now put in, just sufficient to cause a slight turbidness; the bottle has then to be filled up with distilled water, and the solution is ready for use.

In making this solution great care is required not to add an *excess* of ammonia, which can be avoided by allowing the solution to remain *slightly turbid*.

Salted paper is excited with the ammoniacal nitrate of silver solution in precisely the same manner as described for the plain nitrate of silver solution, of course not disturbing the precipitate which settles at the bottom of the bottle.

Printing Positives on Paper.—The frames used for printing have been described, therefore it only remains to say that the negative must be placed upon the glass, face upwards, and the prepared paper, face downwards, upon this, face to face; then the back-board, and the whole screwed moderately together. Very little pressure is required in the case of glass negatives.

The frame may now be carried into the light, and, in the case of a paper negative, exposed to the strongest sunlight; so also may many glass negatives, but a great many also of the latter are better printed by a good diffused light without the sun. This arises from the glass negatives, particularly when varnished, being more transparent; therefore the sunlight, if very intense, is apt to flatten down the picture, whereas by printing in the shade, the darks, by giving more time, become quite as intense, and the whites more brilliant.

Most of the printing frames now used being jointed at the back, the picture may be examined, from time to time, to judge of its intensity, and if not sufficiently printed, closed up again without being shifted, and again exposed to the light.

The printing process, as before observed, is very simple, but requires care, for if the picture be taken off too soon it will not fix up well, and if allowed to remain on too long it becomes too dark. *But it should be borne in mind that the printing must be carried deeper than is wanted in the finished picture, as a certain portion will be taken out in the fixing.* By attention to this, and with the use of the toning bath about to be described, almost any tone of picture may be obtained.

Toning the Picture.—We must now suppose the picture properly printed. The next thing is to immerse it direct in the toning bath, made as follows:

TONING BATH.

Hypo sulphite of soda	-	-	-	2½ ounces.
Chloride of gold	-	-	-	6 grains.
Common salt	-	-	-	40 grains.
Nitrate of silver	-	-	-	1 dram.
Water	-	-	-	1 pint.

Dissolve the nitrate of silver in two ounces of distilled water, then add the common salt, stir well together, and allow the precipitate which forms to subside; pour away the upper clear fluid, and fill up again with water, allow to subside, and again pour off, three separate times; then add to the precipitate eighteen ounces of water and the hypo sulphite of soda, and stir well together until dissolved; lastly, add the chloride of gold, previously dissolved in the remaining two ounces of distilled water, and it is ready for use.

The tone of picture produced by this bath will depend upon the intensity to which the printing has in the first instance been carried; therefore, if we want them to fix up very dark, we must print deep, to give the above solution time to produce the required tone; but if a warm brown is required, then less intensity will produce the result.

Having obtained the required color, which may take from ten minutes to as many hours, remove the print from the toning bath, and fix by immersing it in the following solution:

FIXING SOLUTION.				
Hypo-sulphite of soda	-	-	-	3 ounces.
Water	-	-	-	1 pint. Dissolve.

Immerse the print in this bath for a quarter of an hour, then remove it and wash it with water to remove the fixing solution as much as possible, and then plunge it into a vessel of water, which must be changed five or six times during the twenty-four hours the print must remain in it. After this drain, and pin up to dry.

Too much care cannot be used in removing every trace of the fixing solution, as this, if allowed to remain, causes the picture to fade.

It may be mentioned that the toning bath will "color or tone" some scores of prints, if a grain or two of chloride of gold is added from time to time, when its action is slow, to give the required color. The fixing solution should only be used to fix half a dozen prints, and be then thrown away, and a fresh solution employed for other prints.

But as pictures are not only printed upon salted paper but on the albumenised, it will be necessary to describe the method of making—

Albumenised Paper.—Take any quantity of the white of egg, and mix with it an equal quantity of water. To each ounce of the mixture add ten grains of muriate of ammonia, and beat the whole into a froth. The more effectually this is done the better. Then stand the basin aside, that the clear liquid may settle down, and pour this off into a flat dish.

The paper having been cut into the proper sizes, must be placed down upon this solution, and all air-bubbles avoided. This is best accomplished by beginning at one end and gradually pressing forward. Some considerable practice is required to make the paper properly, for the solution must be clear, bright, and free from air-bubbles.

Each sheet must remain on for a few minutes, and then be pinned up to dry. As soon as this is the case, a hot iron should be passed over the surface, to set the albumen and render it insoluble.

To excite for printing, dissolve two drams of nitrate of silver in three ounces of distilled water, and filter the solution into a flat dish. Float each sheet upon it for ten minutes, and again pin up to dry in the dark.

The mode of using is in every other respect the same as that

described for the ordinary salted paper, but it has many advantages over that, not only in being able to print the most delicate tints, from the picture being so entirely upon the surface, but the sheet, if placed in a portfolio, will keep for days without change; whereas, with the ordinary salted, it must be used the same day as excited.

If the print has an unequal, mottled appearance, it indicates that the sheet of albumenised paper has not been allowed to remain on the nitrate of silver sufficiently long.

PHOTOGRAPHS OF MICROSCOPIC OBJECTS.

Very beautiful copies of microscopic objects can be obtained by the photographic process, especially that with iodised collodion, possessing all the markings and detail of the most minute objects.

The only arrangement necessary for the purpose is the addition to the microscope of a dark chamber, similar to that of the camera-obscura, having at one end an aperture for the insertion of the eye-piece end of the compound body, and at the other, a groove for carrying the ground-glass plate.

This dark chamber should not exceed 24 inches in length (the size which I have found it best to adopt): if extended beyond this, the pencil of light transmitted by the object-glass is diffused over too large a surface, and a faint and unsatisfactory picture is the result. The eye-piece must be removed from the compound body, and the object (being well illuminated by reflection from the concave mirror) must be adjusted and focused upon the ground-glass plate.* In the production of positive pictures a slight difficulty here arises, dependent upon the "over-correction" of the object-glass. The effect of this "over-correction" is to project the blue rays of light beyond the other rays of the spectrum, and as the chemical properties of light reside beyond the violet and blue rays, it becomes necessary that the plane of the sensitive plate should coincide with the foci of these rays, and it must therefore be placed beyond the surface at which the best definition is seen; this amounts to some distance with the lower combinations, and decreases with the increase of magnifying power.

For the production of *negative* pictures, the ordinary illumination is not sufficient, and recourse must be had to the sunbeam, which should be reflected upon the object by the plane mirror when powers are used not exceeding the quarter of an inch combination. It is not necessary here (when producing negatives by the sunbeam) to allow for the "over-correction" of the object-glass, but merely to focus the object carefully upon the ground-glass plate.

In the production of negative pictures, a moment's exposure to the sunbeam is sufficient when using the lowest powers, and with the highest I have varied the time from five to ten seconds.

* The microscope must be placed in a perfectly horizontal position, in order to adapt it to the dark chamber.

HEAT.

HEAT IN ITS PHYSICAL RELATIONS; OR THE PHYSICS OF HEAT.

SYN.—*Caloric, Chaleur, Wärmestoff, Warmematerie.*

HEAT, or Caloric, is supposed to be that substance whose entrance into the body occasions the sensation of heat or warmth. By the absence or loss of heat, we experience the sensation of cold.

Heat is invisible, and is not susceptible of weight. If sulphuric acid and water be mixed, there is a great developement of heat, although the mixture has the same weight as before they were mixed. Iron when heated weighs the same as when cold.

Heat is repulsive. If two bodies easily movable be suspended in vacuo, they repel each other, a proof that heat is repulsive. (Fresnel.)

RADIATION OF HEAT.

Heat possesses the property of spreading itself out in straight lines from the place of its origin. These rays pass through a vacuum, through elastic fluids, and through some liquid and solid bodies. The intensity of heat varies inversely as the square of the distance from the radiant point.

Heat, like light, may be concentrated by concave mirrors. Two mirrors, Fig. 22, are juxtaposed, with their principal axes in the same line.

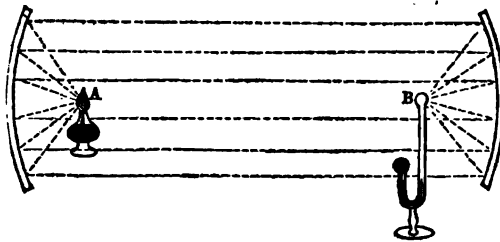


Fig. 22.

A lamp, or hot bail, is placed in the focus A, and a differential thermometer in the focus B, when the latter by its sudden rise indicates that the rays of heat are converged at that point. If a piece of ice is placed at A, the thermometer falls, as in that case

the heat-rays pass from the thermometer to the ice, from B to A. These effects can be produced at a distance of seventy-seven feet. Tinder has been set on fire at that distance by placing a red-hot ball in one focus, and the tinder in the other. But a thermometer placed midway between the two mirrors is not sensibly affected.

When a body is placed in the air, or in vacuo, it radiates its excess of heat, or it absorbs it, depending upon the nature of its own surface. Leslie used the apparatus, Fig. 23, for the purpose of determining the radiating power of different surfaces. The square can was filled with hot water, and its outside was coated with various substances. The thermometer indicated the radiating power of the can, when covered with the substances mentioned below.

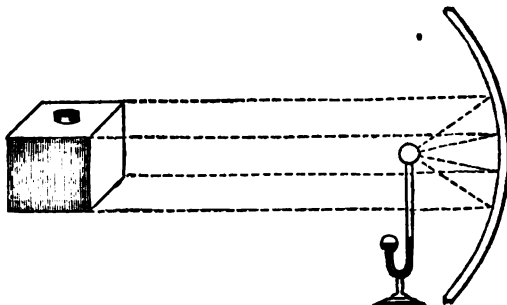


Fig. 23.

The following table will exhibit the relative radiating power of the substances with which the surface of the can was coated, as indicated by the thermometer :

Lampblack,	100	Indian Ink,	88
Water,	100	Ice,	85
Resin,	96	Isinglass,	80
Sealing-wax,	95	Red lead,	80
Crown glass,	90	Graphite,	75
Polished Lead,	19	Polished Iron,	15
do. Tin,	12	do. Copper,	12
Polished Gold,	12		

Each substance has, therefore, a specific radiating and absorbing power, to which are opposed the Retaining and Reflecting powers. The latter, therefore, increase in the same ratio as the former diminish, and conversely. Lampblack radiates five times more heat of boiling water than clean lead, and eight times more than polished tin. The bright metals, therefore, have the lowest radiating power, while those surfaces which are dark and rough have the highest.

When two bodies are so placed that air or empty space intervenes, and are equally hot, the elasticity of the heat is equal in

both, and therefore each will hold the other in check, and the heat will remain at rest in both. But if one of the bodies is hotter than the other, the tension of its heat will be greater, and consequently a quantity of heat will radiate from it to the colder body, until the equilibrium is established.

The calorific rays are possessed of difference of refrangibility as well as the luminous rays. The refrangibility of the rays depends upon the temperature of the source of heat. The hotter the source, the more refrangible the rays emitted from it, and the greater their number. All heated bodies, however, emit rays of all degrees of refrangibility, the nature of the heated body determining the proportion of the refrangible rays. Different bodies exhibit different powers of absorbing these rays. Snow absorbs principally the less refrangible rays and reflects the more refrangible ones. Hence it does not melt so quickly in direct sunshine as in the neighborhood of stones or trees, and other solid bodies, which, when warmed by the sun's rays, emit calorific rays of less refrangibility. Not so quickly when freely exposed to an argand lamp, as under a covering of black paper which does not touch the snow—not so quickly by the rays of an argand lamp as by those from a piece of metal heated to 400° , when both are placed at such a distance that their heating powers are equal. (Melloni.) It appears that the most refrangible rays of heat, when absorbed by bodies, and then emitted by them, are converted into rays of less refrangibility. The greater the radiating power of a body, the more rapidly it cools in vacuo. This also is accelerated by the greater extent of its surface, the smallness of its mass, and its less specific heat.

Those surfaces which radiate heat most efficiently, likewise possess the power of absorbing it. Conversely, those substances which have a feeble radiating and absorbing power, as the metals, also possess the power of strong reflection.

Bodies which allow rays of heat to pass through them are said to be *Diathermanous*. If the heat-rays are allowed to fall upon a piece of glass, a small portion will pass through it. If the temperature of the source be heated to ignition, then the number of the rays which pass through the glass is increased. Those rays which have already passed through a piece of glass, suffer much less diminution by passing through a second. Bodies are possessed of different diathermanous powers. Common salt stands first in its power of transmitting all the heat-rays, although it allows but few light-rays to pass; while most bodies transmit the most refrangible rays, and absorb the less refrangible ones. Of 100 rays of heat from an argand lamp, and falling on very thin plates of the following substances, the number transmitted are as follows: Transparent rock-salt, 92.3; flint glass, 67.0; sulphide of carbon, and protochloride of sulphur, 63.0; double-refracting spar, and rock crystal, 62.0; smoky topaz, 57.0; Brazilian topaz, 54.0; transparent lead spar,

52.0; crown glass, 49.0; white chalcedony, 35.0; translucent heavy spar, 33.0; oil of turpentine, 31.0; fat oil, 30.0; transparent aqua marine, 29.0; translucent borax, 28.0; green Brazilian tourmaline, 27.0; brown balsam of copaiva, 26.0; translucent adularia, 24.0; ether, 21.0; transparent gypsum, 20.0; oil of vitriol, 17.0; nitric acid, alcohol, and citric acid, 15.0; transparent alum, 12.0; water, 11.0.

That portion of the rays which is not transmitted is partly absorbed and partly reflected. If 100 rays of heat fall perpendicularly on a thin plate of rock-salt, 92.3 are transmitted, and 7.7 reflected. If the incident rays are oblique, the reflected rays become greater. As light is converged to a focus by a lens of glass, so the heat-rays are brought to a focus by a lens of rock-salt, the focal distance being greater than that of light. The reason of this is, that light is more strongly refracted than heat. As rock-salt, in respect to heat, resembles transparent glass in respect to light, so most bodies refract the most refrangible rays of heat, as blue glass does those of light. Rock-salt blackened with lampblack, in its transmission of the less refrangible rays of heat, is analogous to red glass in its transmission of the less refrangible rays of light. When the light of the sun is made to pass, first through water, which absorbs the less refrangible, then through glass colored with oxide of copper, which takes up the more refrangible rays of heat, it is totally deprived of its heating power. (Melloni.)

Water transmits the most refrangible rays, but absorbs those less refrangible. When the film of water is very thin (0.3 metre thick), the maximum of heat is found at the commencement of the green, and the heat spectrum extends but a little way beyond the red into the dark space. This explains Seebeck's discovery, that the maximum of heat is found in different parts of the spectrum, according to the nature of the prism. The smaller the number of colorific rays, which any substance transmits, whilst it retains the less refrangible rays the more nearly does the maximum of heat in the spectrum formed by a prism made of that substance approach to the violet; whence, according to Seebeck, a prism of water placed in the yellow, of oil of vitriol in the orange, of crown glass in the red, of flint glass beyond the red; and with a prism of rock-salt, which completely transmits even the least refrangible rays, the maximum of heat is situated, according to Melloni, in the dark space, and as far removed from the red as the red itself is from the violet. With some glass prisms, the maximum of heat approaches more nearly to the violet, in proportion as the ray of solar light passes through a thicker part of the prism, because, in this longer passage through the glass, a greater number of the less refrangible heat-rays are retained. (Melloni.)

According to the investigations of Knoblauch, it appears that the

quality of radiant heat transmitted through substances does not depend so much upon the temperature of the source from which it issues as upon the nature of the body through which it is passed. Each substance is possessed of a certain inherent nature, by which rays of heat pass through it with more or less facility. The thickness of the plates of the substances employed also exerts considerable influence upon the results, as was ascertained by Knoblauch. The capacity which substances possess of transmitting heat does not depend upon their transparency, for there is no relation between the power of transmitting heat and light. Plates of the following substances, being the 0.1081 of an inch thick, or about the tenth of an inch thick, allowed from the flame of an argand lamp very unequal portions of heat-rays to pass through them.

Of 100 incident rays, there were transmitted—

By rock-salt.....	92 rays.
Mirror glass.....	62 "
Rock crystal.....	62 "
Island spar.....	62 "
Rock crystal, smoky.....	57 "
Carbonate of lead.....	52 "
Sulphate of barytes.....	33 "
Emerald.....	29 "
Gypsum.....	20 "
Fluor spar.....	15 "
Citric acid.....	15 "
Rochelle salt.....	12 "
Alum.....	12 "
Sulphate of copper.....	0 "

A piece of smoky rock crystal of a deep brown color, so dark that scarcely any light-rays could pass through it, allowed nineteen rays of heat to pass through it, although a piece of alum fifty-eight times thinner would allow only six heat-rays to pass through it. A species of black glass, almost impervious to the light, allowed the heat-rays to permeate it freely. Thus many bodies are *diathermanous*, or allow the heat-rays to pass through them freely, while others are *diaphanous*, or allow the light to pass unobstructed through them, but are opaque to the heat-rays. Water, of all the diaphanous bodies, is the least diathermanous, as, while it allows the light-rays to pass through it with facility, it transmits heat with the least readiness. But most of the diathermanous bodies belong likewise to the diaphanous class, or are more or less transparent, while those of wood, marble, and metal, which entirely obstruct the passage of light, does that of heat also. The source from which the heat emanates influences greatly the result of its absorption by the same substance. For instance, if a piece of glass $\frac{1}{10}$ th of an inch thick be used, the following sources of heat vary the result of the passage of the thermal rays considerably, as learned by Melloni:

Of 100 rays.	Transmitted.	Absorbed.
From the flame of an oil lamp - - -	54	46
" red-hot platinum - - -	37	63
Blackened copper, heated to 732° F. - - -	12	88
" " " 212° F. - - -	0	100

But rock-salt, above all other bodies, possesses the power of transmitting all the thermal rays, no matter from what source they may be derived—whether the low heat from the hand, or that from a bright flame. Rock-salt may be shaped into lenses, and may be used in that form for the concentration of the rays of heat, as glass is for those of light. It may be cut into prisms, and may be used for decomposing heat, as glass prisms do that of light. It appears that heat, like light, may be separated into different rays, depending partly upon the temperature of the source from which the heat proceeds, and that these rays can be separated, or sifted from each other, by the employment of different media. Flame emits them simultaneously, though in different proportions, but heat of lower intensity than flame emits some of these rays only. The thermic rays emitted from the sun are composed of those which pass most readily through glass, although there are other rays likewise present. The diversity of quality in the emitted rays is greatest in the argand lamp, less in the incandescent platinum, and still less in the alcohol flame, while in the case of the cylinder heated to 8° R., it vanishes altogether. Generally the heat emitted from the most various solid bodies between the temperatures of 144·5° and 234·5° F. is perfectly homogeneous and monochromatic. (Gmelin.)

It is maintained by Melloni and Faber that the rays of heat can be polarised as are those of light, while Powell contends that they cannot. The former persons say that the calorific rays from a body heated to redness may be polarised, so that they will or will not be reflected from a second surface, and afterwards effect a thermometer according to the position in which that surface is placed. Rays of heat can be polarised by transmission through mica or tourmaline, and depolarised by doubly-refracting crystals. Pouillet informs us that the temperature of the sun is between 1461° and 1761·6°, and that the heat which reaches this earth annually from it, is sufficient to melt a stratum of ice, of 31 metres thick, surrounding the globe. The temperature of space, according to the calculations of this philosopher, is —142·6°. According to the experiments of Prof. Faraday, artificial cold has been produced of —166° F. This would then appear to be the temperature of space, as we would conclude that temperature to be equal to that of absolute cold, or the actual zero.

If a number of bodies of various temperatures are placed near each other, it will not be a great while before they will all have either gained or lost heat, and will have all acquired the same temperature. It appears that at all times bodies are radiating heat, so

that there is a constant interchange of temperature between them. In the case we have previously alluded to, of the conjugate mirror, where if a piece of ice is placed in one focus and a thermometer in the other, the mercury quickly falls, is an instance of the interchange of heat between bodies. As cold is a negative quality, this can be accounted for by the fact, that the heat-rays pass from the thermometer to the ice, the thermometer being really the hot body.

Unless we resort to the doctrine of the radiation of heat, we shall not be enabled to account for the deposition of dew. The earth is a good radiator, and therefore of a clear night, by the radiation of its heat, it acquires a temperature of some 10 or 20° lower than the air in contact with it. And this is especially the case with foliage, which possesses powerful radiating properties. As the earth and the latter thus become cooler than the air, there is a deposition of the moisture existing in the air upon their surface, and which is termed dew. The air, at all temperatures, is never deprived of moisture, but when the temperature is up so high as 52° F. it retains $\frac{1}{8}$ th of its volume of vapor, but at 32° F. no more than the $\frac{1}{16}$ th.

That the deposition of dew is the result of radiation is evident from the following circumstances: The accumulation of dew only transpires on a calm, clear night. If the sky is obscured by clouds, then there is no deposition of dew, for the clouds return to the earth the heat radiated by it, and thus prevents its passage into space. A screen placed several inches above the earth prevents the deposition of dew, for the heat radiated by the earth is prevented from escaping by the screen, and is returned again. Gardeners take advantage of this for the purpose of protecting their young plants during the early spring.

Experiment has proved that the deposition of dew upon any object is in a ratio to its radiating power. A bright metal and hair placed side and side will exhibit different powers of radiation, for while the one will be quite wet with dew, the other will not be the least moist. The metal is a poor radiator of heat, while the hair is a very powerful one, and thus the difference in their powers of accumulating moisture.

Ice is made in Calcutta by radiation. The temperature of the nights in that country is never lower than 40° F., but as the sky is clear, the ground radiates heat powerfully. Water is placed in shallow pans, which are imbedded in straw. The radiation from the surface of the water, even at the temperature 8° above the freezing point, converts the water into ice. This does not take place through evaporation, for when the water is removed in situations least favorable to that process, as, for instance, where no current of air can pass over it, then the ice accumulates most rapidly, thus proving that radiation is the sole cause of the freezing. In situations least exposed to currents of air, the frost first makes its

appearance, for in those places the radiation is least disturbed by the currents of air. Even what is termed the conduction of heat is thought by Prof. Graham, and others, to be simply its radiation from one particle of the conducting body to the other.

Whether there exists a central heat in our globe admits not of a doubt. As we continue downwards, there is a rise of one degree for about every 45 feet, and this continues progressively so far as we have yet gone down. For each mile that we progress downwards there is a rise of about 116° F. If this rate of temperature increases as we continue downwards, then at the distance of thirty miles there would be a sufficiently high temperature to melt iron, and which is sufficient to fuse the lavas, basalts, and other rocks that have been thrown out of the craters in a melted state. Although this heat is so intense only thirty and a half miles from the surface of the earth, still it is unable, from the low conducting power of the earth, to affect its surface. It has been calculated by Fourier, that were the earth even composed of solid iron, whose conducting power is much greater than the materials of which it is now composed, that it would require millions of years, for the heat to be conducted from a depth of 100 miles to the surface.*

CONDUCTION OF HEAT.

When heat is prevented from radiation by the adhesive force of liquid or solid bodies, it then diffuses itself through them slowly, or is conducted. Fourier, as has been mentioned before, considers that conduction is merely radiation—the heat, as it passes through the substance, being radiated from one particle to the other. The metals are the best conductors of heat. If the conducting power of gold, which is the best conductor, be assumed = 1000, platinum will be 981, silver 973, copper 898, iron 874, zinc 363, tin 304, lead 180, marble 24, porcelain 12, tiles 11.4. (Despretz.)

Wollaston heated a number of metallic rods, of equal length, breadth, and weight, which were covered with wax. The heat was applied at one end equally to each bar. The wax of the copper

* The heat which we enjoy upon the earth, therefore, is derived from the sun, and it is amply sufficient. The heat evolved from the sun, according to the experiments of M. Pouillet, in a single day would liquefy a shell of ice ten and a half miles thick, enveloping the sun. The intensity of the solar fire is seven times greater than that of the fiercest blast furnace. The mechanical force derived from the sun by the amount of wood growing in one year on one square foot of surface, corresponds to that which would be required to raise a weight of 486,000 lbs. to the height of one foot, while this is only the 1-11th of the whole effect of the sun's rays, of which only one-fifth reaches this earth, and the half of that is lost. Heat is a form of mechanical force. A working-man produces in 24 hours an amount of heating or thermal effect equal to raising nearly fourteen millions of pounds to the height of one foot. This force, whether derived from heat, electricity, or chemical action, is ultimately derived from the solar rays, secreted by vegetation.

was melted for a distance of 3·5 inches, that on the silver for 2·5, and on the platinum and palladium, 1 inch. Solid substances possess different powers of conducting heat; for, while the metals conduct it with great facility, light and porous substances conduct it but poorly. Substances, therefore, of the latter class are generally used for clothing. The finer the fabric of woollen cloth, the more poorly does it conduct; while the down of the eider-duck appears to be the poorest conductor of heat known. Glass is a very poor conductor. A glass rod which is being fused at one end, may be held at the other within an inch or less of the red-hot portion. The following substances are arranged in the order in which they are the most valuable as building materials—those which conduct heat most poorly being placed first, and succeeded consecutively by those which are better conductors:—Plaster and sand, 18·70; plaster of Paris, 20·26; Roman cement, 20·88; beech-wood, 22·44; lath and plaster, 25·55; oak-wood, 33·66; chalk, 56·38; brick, 60·14; fire-brick, 61·70; slate, 100. (Hutchinson.)

If two metals, one a poor conductor of heat and the other a good conductor, be placed in contact, the latter being heated while the former is cold, there will ensue certain musical tones not unlike the vibrations of the glass in the harmonicons. These sounds appear to be connected with the conducting power of the metals. In order to insure the tones, the best conducting metal should be slightly curved at the bottom, and laid upon the worst conductor, which should be flat. The best conductor is then thrown into a state of vibration, or rocking motion, by which the sounds are produced.

Some bodies which we take hold of appear cold to the touch, while others feel comparatively warm. This difference in temperature depends upon the conducting power of the substance. If it is a good conductor, then it feels cold, as in that case it conducts the heat rapidly away from the hand; while, if the body be a poor conductor of heat, it conducts so little of the heat of the hand away as to cause but little of the sensation of cold.

CONDUCTING POWER OF LIQUIDS.

When heat is communicated to the bottom of liquids, it does not pass upwards through conduction, or by radiation from particle to particle, but in consequence of currents in the liquid which flow upward and downward. Heat in this case is communicated by *convection*. The lower portion of the liquid is expanded by the heat, and ascends; while the upper portion, being heavier, descends to take the place of that which has just risen. The consequence is, that there is a circulation of the fluid which continues until the whole liquid has acquired a uniform heat of 212° F. But if heat is applied to the top of the liquid instead of the bottom, then the conducting power of the liquid is manifest, and takes place very slowly.

It is by the convection of heat that apartments are frequently warmed. A tube is carried throughout the house; this tube contains water, which, when heated at the bottom, causes a circulation of the heated water throughout the length of the tube, the colder portions of the water falling to the lower portions of the tube, while the heated water rises to take its place.

The cooling of heated bodies in gases and in the air, takes place partly through radiation and partly through the transference of the heat to the particles of the gas. The latter mode of communication is not affected either by the nature of the surface, or by the absolute temperature, provided the difference of temperature between the heated body and the surrounding air remains the same: so long as the elasticity of the air continues unaltered, its density may vary in any way whatever from change of temperature, without producing any alteration in the rate of cooling. On the other hand, the velocity of cooling by contact varies: 1. With the elasticity of the several kinds of gas—inasmuch as the diminution of the elasticity consequent on mechanical rarefaction lessens the rate of cooling in a proportion which is different in the different kinds of gas. 2. According to the nature of the surrounding gas—being greatest in hydrogen (whether from the greater mobility of that gas, or its greater capacity for heat?), less in olefiant gas, still less in air, still less in carbonic acid, and, according to Davy, slowest of all in chlorine gas. But even when the actual velocity changes, the law of cooling by contact of gas remains always the same, viz., that when the difference of temperature is doubled, the velocity of cooling increases 2.35 fold. (Petit and Dulong.)

EXPANSION OF GASES.

When heat enters into bodies, it expands them. This expansion varies according to the nature of the substance, not only in degree, but also in the law which it follows. By being heated from 32° F. to 212°,

1000 cubic inches of iron	become	1004
1000 " " water	"	1045
1000 " " air	"	1866

Gases are therefore more expansible than solids; for their particles, not being under the influence of cohesion, are easily separated by repulsion, which heat greatly expands. All gases, by the application of the same amount of heat, undergo the same degree of expansion, the rate being uniform at all temperatures. According to the more exact experiments of Magnus and Regnault, the expansion of air from 32° F. to 212° is $\frac{366.7}{1000}$, or $\frac{1}{3}$ of its volume at 32°. Or air at 32° F. expands $\frac{1}{101}$ part of its bulk for every degree of heat added:

491	cubic inches of air at 32° become
492	" " " " 33°
493	" " " " 34°, &c.

The increase being one cubic inch for every degree of Farenheit added. A contraction of one cubic inch takes place for every degree below 32°, thus:

491	cubic inches of air at 32° become
490	" " " " 31°
489	" " " " 30°
488	" " " " 29°, &c.

The expansion of air, when heated from 32° to 212° F., is constantly the same, whether it be subjected to a pressure of $\frac{1}{15}$, $\frac{1}{10}$, $\frac{1}{5}$, 1, 2, 3, 6, or 15 atmospheres. Air heated from 212° to low redness, expands from one measure to 2.25; and at a bright red heat, to 2.50 measures.

Agreeably to the above law, that gases expand the $\frac{1}{273}$ part of their bulk for each degree added, we can easily ascertain the expansion which a certain volume of gas will undergo when heated to any particular temperature; or the contraction which will transpire from cooling. Air at 32° F. has its volume doubled when heated 491°; or when heated 982°, its volume is tripled, &c.

Recent experiments made by Magnus and Regnault have shown that the rate of expansion is not the same for all gases. The differences of expansion, however, are not very considerable, and will scarcely affect the generality of the law of Mariotte. With atmospheric air, carbonic acid, and sulphurous acid, the coefficient of expansion increases with the tension of the gas. The laws, as generally enunciated, that "the expansion of any gas between given limits of the temperature, is independent of the initial density," and "all gases have the same coefficient of expansion," are regarded by Regnault as true *in the limit* only; that is to say, they accord more and more nearly with the results of observation in proportion as the gases are in a more expanded state. (Gmelin.)

EXPANSION OF LIQUIDS.

In liquids, expansion is greater than in solids, for the reason that the expansive force of heat is less resisted by cohesive attraction. If the bulb and part of the stem of a thermometer are filled with water, upon applying heat to the bulb the fluid is seen quickly to rise in the stem.

Some liquids are much more expansible than others. If the following liquids are heated from 32° F. to 212°, they expand thus: alcohol expands $\frac{1}{10}$, fixed oils $\frac{1}{12}$, water $\frac{1}{13}$, mercury $\frac{1}{15}$. Alcohol is therefore nearly six times more expansible than mercury. In the summer, spirits will measure 5 per cent. more than in winter. (Graham.) 100 measures of liquid carbonic acid at -20°, expand to

150 measures at $+ 30^{\circ}$. The expansion of liquid carbonic acid is therefore greater than that of gases. If it is heated from 32° to 86° , twenty volumes of this liquid expand to twenty-nine, which is four times a greater dilation than that of air by the same change of temperature. Sulphurous acid and cyanogen, in the liquid state, are extremely expansible, but not so much so as the liquid carbonic acid.

A great correspondence has been observed in the expansion of alcohol and bisulphide of carbon, although their boiling points are different, that of the former being 173° F., while that of the latter is 116° . These two liquids expand and contract uniformly from the addition and loss of heat. This is also the same with the bromides of ethyle and methyle, and likewise the iodides of ethyle and methyle.

Liquids are more expansible at high than at low temperatures; but mercury is less liable to this increased expansion than any other liquid. This renders the employment of mercury for thermometers very reliable. The rate of expansion of mercury—

From	0°	to	100°	C.	is 1 measure on	$55\frac{1}{2}$
"	100°	"	200°	C.	" 1	" $54\frac{1}{2}$
"	200°	"	300°	C.	" 1	" 53

While the expansion of mercury confined in glass tubes is only 1 on 64.8. The glass tube also expands, which enlarges its capacity; and this compensates for the expansion of the mercury.

Rumford ascertained the contraction of water, for every $22\frac{1}{2}^{\circ}$ in cooling, from 212° F. to the freezing point.

200 measures of water contract,

In cooling	$22\frac{1}{2}^{\circ}$	, or from	212°	to	$189\frac{1}{2}^{\circ}$	.....	18	measures.
"	"	"	"	"	$189\frac{1}{2}$	to	167	.....16.3 "
"	"	"	"	"	167	to	$144\frac{1}{2}$	.....13.8 "
"	"	"	"	"	$144\frac{1}{2}$	to	122	.....11.5 "
"	"	"	"	"	122	to	$99\frac{1}{2}$	..... 9.3 "
"	"	"	"	"	$99\frac{1}{2}$	to	77	..... 7.1 "
"	"	"	"	"	77	to	$54\frac{1}{2}$	..... 3.9 "
"	"	"	"	"	$54\frac{1}{2}$	to	32	..... 0.2 "

Water, in its expansion and contraction by heat, is subject to some peculiarities which demand attention. When water of the temperature of 39° F. is exposed to further cold, instead of contracting, it expands. When water of 39° F. is either heated or cooled, it expands regularly for the same number of degrees either added or subtracted; hence, when cooled to 36° , it rises to the same point as when heated to 44° . At 32° it stands at the same point as at 48° ; and at 20° , at the same point as at 60° . The experiment of Dr. Hope is instructive, and illustrates the expansion and contraction of water very strikingly. A glass jar was filled with water of the temperature of 50° F., and was placed in a cold room. Two ther-

miometers were plunged into the water, one of which was near the surface, and the other at the bottom. The upper thermometer indicated a temperature several degrees higher than the lower one, as the cooling proceeded, until the water reached a temperature of 39.2° . Thus the chilled water fell to the bottom, being condensed by the cold, as will be seen by Fig. 24.



Fig. 24.



Fig. 25.



Fig. 26.

At 40° (or, according to late authorities, 39.2°) the two thermometers remained for awhile steady (Fig. 25); but, as the cooling proceeded, the higher thermometer fell as indicated in Fig. 26.

Among all solid bodies there is but one known which follows this law of expansion by the abstraction of heat at certain temperatures. This is the fusible metal of Rose, which is composed of bismuth 2 parts, lead 1 part, and tin 1 part, by weight. This alloy, when heated from 0° to 44° C., expands. When still further heated, it contracts, so that at 56° C. its density is the same as it was at 0° , and at 69° C. still greater. Beyond this temperature expansion again takes place: at 87.5° C. the alloy is again of the same density as at 0° , and at 94° C., at which it fuses, the same as at 44° C. This alloy cannot, however, be compared to water, as, doubtless, there is an alteration in its constitution which may occur from the change of temperature.

The extraordinary irregularity in the dilation of water by heat, is not only curious in itself, but also of the utmost consequence in the economy of nature. When the cold sets in, the surface of our rivers and lakes is cooled by the contact of the cold air and other causes. The superficial water, so cooled, sinks and gives place to warmer water from below, which, chilled in its turn, sinks in like manner. The progress of cooling in the lake goes on with considerable rapidity, so long as the cold water descends and exposes that not hitherto cooled. But this circulation, which accelerates the cooling of a mass of water in so extraordinary a degree, ceases entirely when the whole water has been cooled down to the temperature of 40° , which is still eight degrees above the freezing-point. Thereafter the chilled surface-water expands, as it loses its heat, and remains at the top, from its lightness, while the cold is very imperfectly propagated downwards. The surface in the end

freezes, and the ice may thicken, but at the depth of a few feet the temperature is not under 40° F., which is high when compared with that frequently experienced, even in this climate, during winter. If water continued to be heavier until it arrived at the freezing temperature, the whole of it would be cooled to that point before ice began to be formed; and the consequence would be, that the whole body of water would rapidly be converted into ice, to the destruction of every being that inhabits it. Our warmest summers would make but little impression upon such masses of ice, and the cheerful climate which we at present enjoy, would be less comfortable than the frozen regions of the pole. Upon such delicate and beautiful adjustments do the order and harmony of the universe depend. (Graham.)

The expansion of bodies by heat greatly varies. For instance :

1000	cubic inches of iron	become	1004
1000	" " " water	"	1045
1000	" " " air	"	1366

While liquid carbonic acid is still more expansible. Gases, it will be perceived, are very expansible; for, not being under the influence of cohesive attraction, like solids and liquids, they are possessed of powerful repulsive properties, a small amount of heat greatly enhancing this expansion. All gases undergo the same increase of volume by the application of the same amount of heat, the rate of expansion continuing uniform at all temperatures.

The expansion of gases has been previously alluded to, and therefore requires no further notice here; but the expansion of fluids in relation to the thermometer, necessarily requires some attention.

Since gases and vapors are the only bodies the expansion of which is uniform, the thermometer cannot give precisely the true temperature, but makes the high temperatures too great. The expansion of the glass which incloses the fluid must be taken into consideration, since it makes their real expansion too great. But as the expansion of glass at high temperatures increases more rapidly than that of gases, the error of the mercurial thermometer is partially corrected by this circumstance. It is likewise ascertained that by the pressure of the external air upon the bulb of the thermometer, it slightly contracts, in time, which has a tendency to slightly elevate the mercurial column from one-half to 1° R., above its previous standard. When thermometers are exposed to temperatures above 300° , the alteration of the zero point amounts to half a degree in four or five years.

The **AIR-THERMOMETER** consists of a glass bulb, with a tube attached to it. The bulb contains air, while the tube is closed with a drop of some not easily volatile liquid, such as sulphuric acid.

The **DIFFERENTIAL THERMOMETER** consists of a glass tube, bent in a U form, with bulbs blown at each end. The tube is filled with fluid, which is driven one way or the other, according as either one

bulb or the other is heated. Thus the Differential Thermometer measures the difference of temperature, but no exact degrees. If one of the bulbs of this thermometer is covered with lampblack, and the other bulb with gold-leaf, the former becomes more strongly heated by exposure to light than the latter, and thus the instrument becomes one susceptible of measuring the intensity of light, or it is converted into a PHOTOMETER. The delicacy of the Differential Thermometer becomes still greater when it is filled with the vapor of alcohol in contact with excess of that fluid instead of air. (Howard.)

The AIR-PYROMETER is a hollow sphere of platinum, fitted with an escape tube. The hotter the fire to which the platinum vessel is exposed, the greater is the quantity of air driven out of it, and thus received over water and measured. (Pouillet.)

The Mercurial Thermometer can only be used for temperatures between -38° and $+350^{\circ}$: the Spirit-Thermometer between the greatest degree of cold known and $+70^{\circ}$.

The METALLIC THERMOMETER of Breguet is composed of three thin strips of platinum, gold, and silver, which are laid on each other, and wound into a spiral. This spiral becomes twisted by the unequal expansion and contraction of these metals by the changes of temperature. This twisting gives motion to an index, which, by passing over degrees, indicates the temperature. This thermometer does not indicate the exact measurement of temperature, as it does the detection of very transient changes.

The METAL PYROMETER consists of a bar of silver or of platinum, which is contained within a tube of porcelain, or sometimes of clay mixed with black-lead. The metal bar, when heated, expands more than the clay, and gives motion to an index, which traverses a graduated arc.

The PYROMETER of Wedgewood consists of cylinders of clay, which contract at high temperatures. The first degree corresponds to 598° C., and each degree is equal to 72° C. This pyrometer gives very uncertain results, and is therefore but little used.

Princep uses alloys of silver and gold, ten parts of which contain 1, 2, 3, 4, 5, 6, 7, 8, or 9 parts of gold. For very high temperatures he uses alloys of gold and platinum, containing 99, 98, 97, &c., per cent. of gold. They are made into flattened buttons. These alloys he places in separate cupels in the fire, the strength of which he wishes to determine, and ascertains which of them is fused. From a comparative estimate with an air-pyrometer made of gold, it appears that silver melts at 999° C.; 9 parts of silver and 1 of gold, at 1049° C.; 8 of silver and 2 of gold, at 1070° C.; 6 of silver and 4 of gold, at 1099° C.; and 3 of silver with 7 of gold, at 1379° C. An alloy containing 30 parts of gold and 70 of platinum is infusible, even in the strongest blast-furnace. (Gmelin.)

The thermometer of Reaumur is divided into 80 degrees, being the interval between the freezing and boiling point. The thermom-

eter of Celsius, being generally designated the Centigrade, is divided from the freezing to the boiling point of water into 100 degrees. That of Delisle is divided into 150, and that of Fahrenheit into 180 equal parts. The thermometers of Reaumur and Celsius have their zero at the melting-point of ice; that of Delisle at the boiling-point of water, while that of Fahrenheit is placed 32° below the melting-point of ice: $9^{\circ} \text{ F.} = 7.5^{\circ} \text{ D.} = 5^{\circ} \text{ C.} = 4^{\circ} \text{ R.}$, while a correction must be made for the different positions of zero.

For the common thermometer, mercury is the most appropriate fluid that we can make use of. But if the instrument is to be used for very low temperatures, alcohol should be resorted to, as mercury becomes solid at -39° F.

In the thermometer of Fahrenheit, the freezing-point of water, or rather its melting-point, is put down at 32° , while thirty-two degrees below that is put down as zero. This temperature was thought by Fahrenheit to be the absolute negation of heat, and was therefore marked zero on his thermometric scale. In the instrument of Celsius, a Swedish philosopher, the space between the freezing and the boiling of water, was divided into 100 equal parts. This instrument, under the designation of the centigrade thermometer, is generally made use of in Europe, except in England. The freezing-point of water is termed 0, or zero, and the boiling-point is 100° . In the thermometer of Reaumur the freezing-point of water is, as is the case with that of Celsius, 0, while the boiling-point is 80° . A simple rule may be given for converting centigrade degrees into those of Fahrenheit. 100 degrees Centigrade being equal to 180° of Fahrenheit, $10 \text{ degrees C.} = 18 \text{ degrees F.}$, or $5 \text{ degrees C.} = 32$. Thus to find the degree F. corresponding with 50° C.

$$\begin{array}{r}
 50 \\
 9 \\
 \hline
 5 \overline{)450} \\
 90 \\
 \hline
 \text{add } 32 \\
 \hline
 122 \text{ degrees F.}
 \end{array}$$

The following table can be consulted for the corresponding degrees of the three thermometers:

R.	C.	F.	R.	C.	F.
+	+	+	+	+	+
320	400	752	304	380	716
316	395	743	300	375	707
312	390	734	296	370	698
308	385	725	292	365	689
288	360	680	108	135	275
284	355	671	104	130	266
280	350	662	100	125	257

EXPANSION OF LIQUIDS.

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R.	C.	F.	R.	C.	F.
+	+	+	+	+	+
276	345	653	96	120	248
272	340	644	92	115	239
268	335	635	88	110	230
264	330	626	84	105	221
260	325	617	80	100	212
256	320	608	76	95	203
252	315	599	72	90	194
248	310	590	68	85	185
244	305	581	64	80	176
240	300	572	60	75	167
236	295	563	56	70	158
232	290	554	52	65	149
228	285	545	48	60	140
224	280	536	44	55	131
220	275	527	40	50	122
216	270	518	36	45	113
212	265	509	32	40	104
208	260	500	28	35	95
204	255	491	24	30	86
200	250	482	20	25	77
196	245	473	16	20	68
192	240	464	12	15	59
188	235	455	8	10	50
184	230	446	4	5	41
180	225	437	0	0	32
176	220	428	—	—	+
172	215	419	4	5	23
168	210	410	8	10	14
164	205	401	12	15	5
160	200	392	14.82	17.78	0
156	195	383	16	20	— 4
152	190	374	20	25	13
148	185	365	24	30	22
144	180	356	28	35	31
140	175	347	32	40	40
136	170	338	36	45	49
132	165	329	40	50	58
128	160	320	44	55	67
124	155	311	48	60	76
120	150	302	52	65	85
116	145	293	56	70	94
112	140	284	60	75	103
64	80	112	76	95	139
68	85	121	80	100	148
72	90	130			

^a	^b	^c	^d	^e	^f
1° R.=1.25° C.=2.25° F.		1° C.=0.6° R.=1.8° F.		1° F.=0.55° C.=0.44° R.	
2 =2.5 =4.5		2 =1.6 =3.6		2 =1.11 =0.88	
3 =3.75 =6.75		3 =2.4 =5.4		3 =1.67 =1.33	
		4 =3.2 =7.2		4 =2.22 =1.77	
				5 =2.78 =2.22	
				6 =3.33 =2.66	
				7 =3.89 =3.11	
				8 =4.44 =3.55	

How many degrees Fahrenheit = 273 Celsius! According to the table 270 Cels. = 518° F., the 3° C. over are equal by *d*. to 5.4° F.; and these added give 518° + 5.4° = 523.4° F. How many degrees of Celsius = 676° Fahrenheit! By the table 671° F. = 355° Cels.; and by *d* 5° F. = 2.78° C.; therefore together 671° F. = 355° + 2.78° = 357.78° C.

Heat imparts to many ponderable bodies particular colors, which vary according to the quantity of heat contained in the bodies. When heated they assume certain colors, differing from those they possess when cold, but upon cooling their original colors return. This change of color does not implicate any chemical change. Sulphur, generally of a pale yellow color, when heated just below its melting-point becomes brown. Hyponitric acid at -20° C. is colorless, at 0° is pale yellow, and at +20° is orange-yellow. Further increase of heat increases the depth of its color. Titanic, tantalic, and molybalic acids, which are white at common temperatures, become of a lemon-yellow color when they are heated. The green oxide of chromium becomes brown by heat, while the orange-colored chromic acid becomes red. The lemon-yellow tungstic acid becomes orange-yellow by heat. Pale gray anhydrous tersulphate of chromium becomes the color of peach-blossoms when heated. The yellow neutral chromate of potassa, or soda, becomes aurora-colored by heat, while the orange bisulphide of arsenic becomes red. The yellow tersulphide of arsenic when heated changes color, varying from red to brown. The white oxide of antimony, and the white antimonious acid, change to lemon-yellow by heat. The pale-yellow antimonious acid becomes brownish yellow when heated. The yellow oxide of bismuth varies from orange to red-brown by heat. The pale-yellow oxide of zinc becomes bright yellow. The orange-yellow sulphide of cadmium by heat becomes first brownish and then crimson-red. The white peroxide of tin becomes orange-yellow. The yellow oxide of lead gets brown-red when heated, while the scarlet-red minium becomes violet. The following salts also become of the colors attached to them when heated: Yellow chromate of lead, brown; brown-red peroxide of iron, dark brown; colorless aqueous solution of acid pernitrates of iron, reddish-yellow; red suboxide of copper, brownish gray; brownish-black protoxide of copper, deep black; red oxide of mercury, brownish-black; scarlet cinnabar, carmine-red; white protosulphite of

mercury, first yellow, then red; yellow basic protonitrate of mercury, red; and the yellow di-iodide of mercury, red. (Gmelin.)

SPECIFIC HEAT.

Different bodies at the same temperature contain different quantities of heat, whether we compare them with regard to weight or volume. Equal weights of iron, sulphur, and lead, for instance, heated to 212° F., when placed in contact with ice, cause a certain quantity of it to melt, but the quantity of water produced is very different with the three substances—the sulphur melting six and a half times, and the iron nearly four times as much ice as the lead. Now, if these three bodies contained equal quantities of heat, the ice melted by each would be equal. If we were to heat equal weights of sulphur, iron, and lead up to the same temperature with the same spirit-flame, we should require to burn for that quantity of lead which would require one ounce of alcohol, four ounces of that fluid for iron, and six and a half ounces for sulphur. Therefore, different bodies require different quantities of heat to raise their temperature equally, and disengage unequal quantities of heat in cooling through the same number of degrees of temperature. The different quantity of heat, therefore, required by equal weights of bodies to bring them up to the same degree of temperature, is called *Specific Heat*, when the bodies are compared with regard to their weight, and *Relative Heat* when they are compared with regard to their volume. It appears that 16 parts of sulphur by weight melt as much ice as 28 parts of iron, and 104 parts of lead. These numbers correspond with the equivalent or combining proportions of these substances. Thus it appears that equivalents of bodies absorb equal quantities of heat in acquiring the same temperature. If bodies of different temperatures, and of different capacities for heat, are mixed together, the temperature of the mixture will not be the mean between the temperatures of the bodies; that is, equal weights of bodies of unequal capacities for heat, when brought to the same temperature, raise or lower the temperature of a certain quantity of water through a different number of degrees, or they will melt unequal quantities of ice. Bodies of equal size, and equally heated, which are of different capacities for heat, require different times to cool down to the same point in the same medium, provided the radiating power of the surfaces are the same in all. Gases require different times to produce in them equal expansion, if submitted to equal heat.

For the determination of the specific heat of gases, Dulong availed himself of the velocity of sound. This he effected by forcing the gases through a flute, and determining the pitch of the sound.

The following table will give the specific heat of elastic fluids at the ordinary pressure of the atmosphere:

Specific Heat of Elastic Fluids at the ordinary Pressure of the Atmosphere.

	SPECIFIC HEAT.		RELATIVE HEAT.	
	that of water = 1	that of air = 1	that of air = 1	
Air.....	0.2500 0.2669 0.3048	1.0000	1.0000	Clement & Desormes. De la Roche & Bérard. Suermann.
Oxygen gas.....	0.1958 0.2361 0.2750	0.7828 0.8848 0.9028 0.9069	0.8080 0.9765 0.9954 1.0000	Apjohn. De la Roche & Bérard. Suermann. Clem. & Des., Dela Rive & Mar., Haycraft, Dulong.
Hydrogen gas.....	8.2938 6.1892	9.5774 12.2401 14.428	0.6640 0.9088 1.0000	Clement & Desormes. De la Roche & Bérard. De la Rive & Marcet, Haycraft, Dulong. Suermann.
Chlorine gas		21.2064	1.4590	Apjohn.
Nitrogen gas.....	0.2754 0.8138	1.0818 1.0298	1.0000 1.0005*	De la Rive & Marcet. De la Roche & Bérard. Suermann.
Vapor of water.....	0.8470	1.0741	1.0480	Apjohn.
Carbonic oxide gas	0.8123	8.1360 1.0258 1.0289 1.0802	1.9600 0.9925 0.9960 1.0000	De la Roche & Bérard. Suermann. Apjohn. De la Rive & Mar., Dulong.
Carbonic acid gas	0.2884 0.2124	1.0805 0.6557 0.6925	1.0840 1.0000 1.0655	De la Roche & Bérard. Haycraft. Suermann.
		0.7838	1.1750 1.1950	Dulong. Apjohn.
	0.9210	0.8280 0.9885	1.2220 1.2588 1.5000	De la Rive & Marcet. De la Roche & Bérard. Clement & Desormes.
Sulphurous acid gas....		0.4507	1.0000	De la Rive & Marcet.
Sulphuretted hydrogen.		0.8485	1.0000	" "
Hydrochlor. acid gas ...		0.7925	1.0000	" "
Nitrous oxide gas		0.6557	1.0000	" "
	0.2240	0.7354	1.1229 1.1600 1.1930	Suermann. Dulong. Apjohn.
	0.2369	0.7827 0.8878	1.8508	De la Roche & Bérard.
Nitric oxide gas.....		0.9616	1.7000	De la Rive & Marcet.
Ammoniacal gas		1.6968	1.0000	" "
Cyanogen gas.....		0.5547	1.0000	" "
Olefant gas.....			1.0660 1.5810 1.5580 1.5809	Haycraft. Dulong. De la Roche & Bérard. De la Rive & Marcet.

* This number cannot be right; for 1.0298 . 0.9757 = 1.0043.

All simple gases, according to De la Rive and Marcet, have the same relative heat.

If the quantity of heat required to raise by 1° the temperature of air inclosed in a vessel with rigid sides be assumed = 1·000, the quantity required to produce the same rise of temperature in an equal quantity of air confined under the same pressure, in such a manner that, while the pressure remains constant, it can expand freely when heated, will be 1·421; and if it be again reduced by pressure to its former bulk, this quantity 1·421 of heat, corresponding to the increase of volume, must be set free. A distinction, therefore, must be made between relative heat under constant volume, and relative heat under constant pressure. (Dulong.)

Air, oxygen, hydrogen, and carbonic oxide gas have the same relative heat under constant pressure, hence it may be surmised that they have likewise the same relative heat under constant volume, and therefore that they evolve the same quantity of heat when subjected to the same pressure. Carbonic acid gas under the same pressure shows a rise of temperature of only $0\cdot337^{\circ}$, nitrous oxide gas of $0\cdot343^{\circ}$, and olefiant gas of $0\cdot240^{\circ}$.

The following table will give the specific heat of a variety of substances according to the determination of M. Regnault:

Substances.	Specific heat of equal weights.	Substances.	Specific heat of equal weights.
Water	1000	Zinc	98·55
Ice	518	Copper	95·15
Oil of Turpentine, at $63\cdot5^{\circ}$ F. 426		Arsenic	81·40
“ “ at 50° F. 414		Silver	57·01
Wood charcoal	241	Tin	56·23
Sulphur	208	Iodine	54·12
Glass	198	Antimony	50·77
Diamond	147	Gold	32·44
Iron	118·79	Platinum	32·48
Nickel	108·68	Mercury	33·82
Cobalt	106·96	Lead	31·40
Bismuth			30·84

Of all liquid bodies, water has the greatest capacity for heat—hence the sea, which covers so large a proportion of the globe, is a great magazine of heat, and has a beneficial influence in equalising atmospheric temperature. Mercury has a small specific heat, so that it is quickly heated or cooled, another property which recommends it as a liquid for the thermometer, imparting as it does great sensibility to the instrument. (Graham.)

With the increase of temperature, the capacity of bodies for specific heat increases. If the specific heat of the following substances be ascertained while they are at 100° , by immersing them into cold water, and noticing the increase of temperature, and then by heating them up to 300° , and again immersing them in cold water, the following differences of specific heat will be observed. Iron with

the first temperature (100°) has a specific heat of 0.1098, and at the second temperature that of 0.1218; mercury, the first is 0.033, the second 0.035; zinc, the first is 0.0927, the second 0.1015; antimony, the first is 0.0507, the second 0.0549; silver, the first is 0.0557, the second 0.0611; copper, the first is 0.0949, the second 0.1013; platinum, the first is 0.0335, the second 0.0355; glass, the first is 0.177, the second 0.190.

Those metals which, when heated, expand most rapidly, increase most in specific heat. The relative heat increases in so far as when the expansion amounts to $\frac{1}{100}$, the increased capacity for heat is about $\frac{1}{10}$. (Dulong and Petit.)

The greater the atomic weight of any substance, the smaller will be the number of atoms of it required to make up a given absolute weight. Since, for example, an atom of hydrogen weighs 1, an atom of sulphur 16, and an atom of silver 108, a pound of sulphur must contain $\frac{1}{16}$, and a pound of silver $\frac{1}{108}$ as many atoms as a pound of hydrogen. If, then, the specific heat (capacity for heat referred to a given weight) of any substance be multiplied into its atomic weight, the product will give the capacity for heat referred to a given number of atoms. (Gmelin.)

The following table will give the results as attained by the ablest experimenters:

Capacity for Heat of the Atoms of Elementary Substances.

Substances.	Specific Heat.	Atomic Weight.	Product.	Substances.	Specific Heat.	Atomic Weight.	Product.
Oxygen gas	0.2361	8.	1.8888	Antimony.....	0.0508	129.	6.5582
Hydrogen gas..	8.2986	1.	8.2986	Tellurium.....	0.0515	64.	3.2960
Nitrogen gas...	0.2754	14.	8.8556	Bismuth.....	0.0808	106.4	8.2771
Diamond	0.1469	6.	0.8814	Zinc.....	0.0955	32.2	3.0751
Graphite.....	0.2019	6.	1.2114	Cadmium.....	0.0567	55.8	3.1639
Charcoal.....	0.2009	6.	1.2054	Tin.....	0.0562	59.	3.3158
Do.	0.2415	6.	1.4490	Lead.....	0.0814	103.8	8.2592
Do.	0.2364	6.	1.7784	Iron.....	0.1188	27.2	3.0954
Phosphorus....	0.1887	31.4	5.9250	Cobalt.....	0.1070	29.6	3.1672
Sulphur	0.2026	16.	3.2416	Nickel.....	0.1086	29.6	3.2146
Selenium	0.0837	40.	3.3480	Copper.....	0.0951	31.8	3.0242
Iodine.....	0.0541	126.	6.8166	Mercury.....	0.0833	101.4	8.3766
Bromine.....	0.1850	78.4	10.5840	Silver.....	0.0570	108.1	6.1617
Tungsten.....	0.0864	95.	8.4580	Gold.....	0.0324	199.	6.4476
Molybdenum...	0.0722	48.	3.4656	Platinum.....	0.0324	98.7	3.1979
Manganese.....	0.1441	27.6	3.9772	Palladium.....	0.0598	58.4	3.1666
Arsenic.....	0.0814	75.2	6.1218	Iridium.....	0.0868	98.7	8.6322

The specific heats of bodies vary inversely as their atomic weights, so that the atom of one body, irrespective of its volume, requires the same amount of heat to raise its temperature to a given degree, as the atom of another body. In the generality of substances, the product of the specific heat into the atomic weight is nearly 3.2. Phosphorus, iodine, arsenic, antimony, silver, and gold exhibit twice

as much capacity for heat in the same number of atoms as most other substances. The capacity for heat of liquid bromine is three times as great as any other substance, but were it solid its capacity would be only twice as great. Carbon, crystallised, has a capacity for heat of one-quarter, that of graphite is one-third, and that of charcoal one-half the ordinary amount.

The specific heat of a compound is diminished by increasing its density. Thus peroxide of iron and protoxide of nickel have their specific heat diminished by strong ignition. Dimorphism appears to exert no great influence on specific heat. (Neumann.) The specific heat of the following isomeric liquids was determined by Regnault.

Oil of Turpentine,	0.4672	Oil of Lemons,	0.4879
Terebene,	0.4656	Oil of Oranges,	0.4886
Terebilene,	0.4580	Oil of Juniper,	0.4776
Camphilene,	0.4518	Petrolene,	0.4684

In the following table, the capacity for heat of compounds is compared with the atomic weight, and thus the capacity for heat of compounds is found.

Capacity for Heat of the Atoms of Compounds.

No.	Substance.	Specific Heat.	Atomic weight.	Product.	No.	Substance.	Specific Heat.	Atomic weight.	Product.
1	Cu ₂ O	0.1178	71.6	7.688		L Cl	0.2650	41.8	11.077
2	H O, ice	0.7200	9	6.480		Ag Cl	0.0911	143.5	18.078
3	Mg O	0.2489	20.7	5.049	16	Ba Cl	0.0896	104	9.318
	Y O	0.1847	40.2	5.415		Sr Cl	0.1199	79.4	9.580
	Mn O	0.1570	85.6	5.589		Ca Cl	0.1642	55.9	9.179
	Zn O	0.1320	40.2	5.306		Mg Cl	0.1946	48.1	8.860
	Pb O	0.0509	111.8	5.691		Mn Cl	0.1425	68	8.977
	Ni O	0.1588	87.6	5.952		Zn Cl	0.1362	67.6	9.207
	Hg O	0.0518	109.4	5.687		Sn Cl	0.1016	94.4	9.591
4	Mn ₂ O ₄	0.1651	114.8	18.952		Pb Cl	0.0664	189.2	9.248
	Pb ₂ O ₄	0.0611	848.4	20.982		Hg Cl	0.0689	186.8	9.425
	Fe ₂ O ₄	0.1641	118.6	19.063	17	Ti Cl ₃	0.1914	95.3	18.240
5	Al ₂ O ₃	0.2178	51.4	11.169		Sn Cl ₂	0.1476	129.8	19.158
6	Cr ₂ O ₃	0.1798	80.2	14.404	18	P Cl ₃	0.2092	187.6	23.788
	Bi ₂ O ₃	0.0605	286.8	14.326		As Cl ₃	0.1760	181.4	31.926
	Fe ₂ O ₃	0.1669	78.4	13.085	19	K Br	0.1182	117.6	13.818
7	Si O ₂	0.1913	80.8	5.892		Na Br	0.1884	101.6	14.061
	Ti O ₂	0.1708	40.5	6.897		Ag Br	0.0789	186.5	18.782
	Sn O ₂	0.0988	75	6.997	20	Pb Br	0.0588	182.2	9.711
8	Mn O ₂	0.1910	43.6	8.328	21	Cu ₂ I	0.0687	189.6	18.025
9	B O ₂	0.2374	84.8	8.261		Hg ₂ I	0.0395	328.8	12.987
10	W O ₂	0.0798	119	9.496	22	K I	0.0819	165.2	13.530
	Mo O ₂	0.1824	72	9.533		Na I	0.0866	149.2	12.950
11	As O ₂	0.1279	115.2	14.784		Ag I	0.0616	2.4.1	14.430
	Sb O ₂	0.0901	158	18.785	23	Pb I	0.0427	229.8	9.812
12	Sb O ₄	0.0953	181	15.348		Hg I	0.0420	227.4	9.551
13	Ca F	0.2082	39.2	8.164	24	Cu ₂ S	0.1212	79.6	9.647
14	Cu ₂ Cl	0.1388	99	13.692	25	Zn S	0.1280	48.2	5.929
	Hg ₂ Cl	0.0520	338.2	12.386		Sn S	0.0836	75	6.270
15	K Cl	0.1729	74.6	12.898		Pb S	0.0509	119.8	6.098
	Na Cl	0.2140	58.6	12.540		Fe S	0.1857	48.2	5.862

No.	Substance.	Specific Heat.	Atomic w'ght.	Product.	No.	Substance.	Specific Heat.	Atomic w'ght.	Product.
	Co S	0.1251	45.6	5.704		Na O, B O ₃ ...	0.2571	68	16.989
	Ni S	0.1281	45.6	5.841	44	Pb O, B O ₃ ...	0.0905	146.6	13.267
	Hg S	0.0480	117.4	6.017	45	K O, 2B O ₃ ...	0.2197	116.8	25.661
26	Ag S	0.0746	124.4	9.258		Na O, 2B O ₃ ...	0.2882	100.8	24.010
27	Bi S	0.0600	260.8	15.648	46	Pb O, 2B O ₃ ...	0.1141	181.4	20.698
28	Cs S	0.3290	88	12.502	47	K O, Cr O ₃ ...	0.1850	99.8	18.870
29	Mo S	0.1238	80	9.884	48	K O, 2Cr O ₃ ...	0.1894	151.4	28.675
	Sn S	0.1198	91	10.856	49	H O, S O ₃ ...	0.8490	49	17.101
30	Fe S	0.1801	59.2	7.702	50	K O, S O ₃ ...	0.1801	87.2	16.576
31	As S	0.1111	107.2	11.910		Na O, S O ₃ ...	0.2811	71.2	16.454
32	As S	0.1182	128.2	13.946	51	Ba O, S O ₃ ...	0.1128	116.6	13.153
33	Sb S	0.0907	177	16.054		Sr O, S O ₃ ...	0.1428	92	13.188
34	Co As	0.0920	92	9.642		Ca O, S O ₃ ...	0.1854	68.5	12.700
35	Sn Bi	0.0400	165.4	6.616		Mg O, S O ₃ ...	0.2216	60.7	18.451
36	Sn Bi	0.0450	224.4	10.098		Pb O, S O ₃ ...	0.0848	151.8	12.878
37	Pb Sb	0.0388	386.6	18.060	52	2Pb O, P O ₅ ...	0.0798	406.8	32.468
38	Pb Sn	0.0407	162.8	6.626	53	2K O, P O ₅ ...	0.1910	165.8	31.668
39	Pb Sn	0.0451	221.8	10.008		2Na O, P O ₅ ...	0.2282	138.6	30.546
40	K O, C O ₂ ...	0.2162	69.2	14.961	54	2Pb O, P O ₅ ...	0.0821	295	24.219
	Na O, C O ₂ ...	0.2727	58.2	11.508	55	Ca O, P O ₅ ...	0.1992	99.9	19.900
41	Ba O, C O ₂ ...	0.1104	98.6	10.885	56	3Pb O, As O ₃ ...	0.0728	450.6	32.804
	Sr O, C O ₂ ...	0.1448	74	10.715	57	K O, As O ₃ ...	0.1568	162.4	25.888
	Ca O, C O ₂ ...	0.2086	50.5	10.584		K O, Cl O ₃ ...	0.2096	122.6	25.697
	Mg O, C O ₂ ...	0.2220	42.7	9.479		K O, N O ₃ ...	0.2387	101.2	24.166
	Pb O, C O ₂ ...	0.0814	188.8	10.891		Na O, N O ₃ ...	0.2782	85.2	23.708
	Fe O, C O ₂ ...	0.1984	57.2	11.062		Ag O, N O ₃ ...	0.1485	170.1	24.109
42	2Mg O, Si O ₂ ...	0.2056	72.2	14.844	58	Ba O, N O ₃ ...	0.1528	180.6	19.890
	2Zr O, Si O ₂ ...	0.1456	91.6	13.337		Sr O, N O ₃ ...	0.1683	106	17.840
43	K O, B O ₃ ...	0.2049	82	16.802	59	Ca O, S O ₃ , 2H O	0.2728	86.5	23.597

The simple atoms by which a compound atom is formed, retain therein the same capacity for heat that they possess when separate; and consequently the heat capacity of a compound atom is the sum of the heat capacities of those atoms which compose it. We can only reconcile some instances, as those of carbon and oxygen, by supposing that their heat capacities vary by simple multiples, according to the compound in which they exist. Exact agreement is not to be expected, since—as is shown by the great differences between the results obtained by different observers—it is only in the case of a few substances that the specific heat has been exactly determined; and moreover, the specific heat of the same body varies according to circumstances. The capacity of bodies for heat may be attributed to their adhesion to that element, and this adhesion in the atoms of most bodies may be supposed to be of the same strength, so that these atoms when immersed in a uniform medium of heat and exposed to the same temperature, will absorb equal quantities of heat. Since the heat which is attached to bodies by adhesion and expands them has lost absolutely nothing of its elasticity, and leaves the bodies as soon as the temperature of any neighboring body becomes lower, even in the slightest degree, the heat thus retained in bodies is called Free, Uncombined, or Sensible Heat. (Gmelin.)

HEAT IN ITS CHEMICAL RELATIONS; OR THE CHEMISTRY OF HEAT.

All fluids, whether liquid or gaseous, are regarded by chemists as matter in combination with heat. If heat were abstracted from substances they would exist as solids. When heat has been added to solid substances they pass into the fluid or gaseous state. In this change, part of the heat becomes insensible, which is manifest to the feelings, and is indicated by the thermometer. This heat then exists in the substance in a state of chemical combination, by which it loses its characteristic quality of elasticity. When these bodies assume their condensed state, this heat is released, and assumes its sensible state, which is indicated by the thermometer. This combined or chemical heat is termed *Latent* or *Combined* heat, and *Heat of Fluidity*. We must not suppose that solid bodies contain no latent heat, for it is not only highly probable that such is the case, but late investigations seem to prove it.

THE FORMATION OF LIQUIDS.

Heat has the property of presenting matter to us in three dissimilar conditions, namely, solid, liquid, and gaseous. The state of a body depends upon the temperature in which it is placed. In the lowest temperatures nearly all are solid, an increase of heat converts them into liquids, and if the process continues, they are changed into gases. The particular temperature at which bodies undergo these changes varies, some altering their condition at a low, while others require a high heat. The melting-point is very different in different substances, but of each individual body it is perfectly constant, for as long as any of the substance remains to be fused, it renders latent the heat that may be in excess, and it is not until the fusion is completed, that the thermometer gives indication of increasing temperature. If a substance has a great affinity for heat, it soon fixes it, even when diffused through the medium in small quantity; if the affinity is slight the quantity of heat surrounding the body must be greater in order that its expansive tendency may be overcome. Mercury fuses at -40° , ice at 32° , sulphur at $+228^{\circ}$; many metals fuse below a red heat, others only at the highest attainable temperatures, while some substances, as carbon, resist the most intense heat the chemist has produced.

Some bodies in passing from the solid to the liquid condition assume an intermediate one, in which the particles adhere together, as is the case with tallow, wax, and several other substances. The great majority of bodies, however, have no such intermediate condition, but pass directly from the solid into the liquid. If we diminish the quantity of heat in the surrounding medium, the liquid body first gives up its uncombined heat, and then, if the process be carried still farther until we reduce the temperature below the freezing-point, the tendency of the heat to diffuse itself, overcomes its affin-

ity for the body, and the liquid is changed into a solid condition. The freezing-point, or the temperature at which a body solidifies, generally coincides with the melting-point; for when heat is applied to a solid body its temperature does not rise above the melting-point until the quantity of heat required to melt it has been absorbed and rendered latent, so when a substance is cooled, it does not generally pass below the melting-point before solidification takes place, for the same amount of heat that was absorbed in order to convert the solid into a liquid, must be changed into sensible heat and given out before the liquid can again assume the solid condition. Nevertheless, under certain circumstances liquids can be cooled several degrees below their usual freezing-point before solidifying. If we take due precautions, we may expose a small quantity of water as 5° or 8° below the freezing-point, without producing congelation. In making the experiment great care must be taken that the water be cooled without the slightest agitation, and that no angular body be in contact with it, for the moment agitation is produced congelation commences, and the temperature raises to 32° . Although we may thus cool a substance several degrees below its freezing-point without producing congelation, we cannot heat a solid the smallest part of a degree above its melting-point without producing liquefaction.

Dr. Black was the first to call the attention of chemists to the remarkable fact of the disappearance of a large quantity of heat during liquefaction. Prior to his time, fluidity was considered as produced by a very small addition of heat to that contained in a body heated up to the melting-point. If this were so, there would be a speedy passage of ice into water as soon as the melting process commenced. If we expose a mass of ice in a warm room, and watch the phenomena, we will find warm currents of air blowing upon it, while a cool current is descending from it; the warm currents surrender a portion of their heat, and becoming cooler and denser sink, and the mass of ice is slowly converted into water, in which if we place the thermometer we find the same degree of heat indicated as if applied to the ice itself. The same phenomena are exhibited when we melt ice by means of warm water. If we take a pound of water at 32° , and mix it with another pound having the temperature of 172° , we will have two pounds of water indicating a temperature of 102° . But if we take a pound of ice at 32° , and mix it with a pound of water at 172° , the ice is melted, and we have two pounds of water having a temperature of 32° . Consequently 140° of heat have been absorbed and entered into a state of chemical combination in order to convert the pound of ice into water. The heat that has disappeared has not been destroyed, but remains latent in the water, to be again given out, when it freezes. A disappearance of heat always ensues when solid bodies are converted into fluids, but an evolution of heat, on the contrary, when liquids are changed into solids. Even solid bodies are

probably affected by an increase or diminution of latent heat, and metals may owe their malleability and ductility to the quantity of heat they have rendered latent. When iron is hammered, heat is disengaged and the metal becomes brittle. But if we again place it in the furnace and subject it to heat, its malleability is restored. When a solid is liquefied without the application of artificial heat, it abstracts from surrounding bodies the necessary heat, and cold is generally produced. Thus the dissolving of salts in liquids causes a reduction of temperature. It is upon this principle that freezing mixtures are produced. The salt has an affinity for water, and becomes fluid, a transformation that implies the rendering of heat latent. If we take a mixture composed of five parts of muriate of ammonia, and five of nitrate of potash, and dissolve them in sixteen parts of water, we may reduce the temperature from $+50^{\circ}$ to 10° , a reduction of 40° . We may vary the experiment by taking five parts of powdered sulphate of soda and eight of undiluted muriatic acid, in which case the temperature may sink from 50° to 0° . The vessel in which the experiment is made becomes covered with hoar-frost from the condensation of the vapor in the surrounding air, and if we immerse, during the process, a glass tube containing water, it is speedily frozen. Snow or ice, and salt, mixed together liquefy, and produce cold, and it is by a mixture of this kind that confectioners prepare their ices. By an admixture with salt, the freezing-point of water is lowered: if we mix one part of salt with four of water, we may lower the temperature to as low as 4° before producing congelation—a provision of Nature that keeps our bays and salt-water inlets navigable in winter, when our lakes and rivers are frozen up. If we wish to produce more intense cold than can be obtained by the admixture of salts and liquids, we resort to the evaporation of highly volatile liquids.

VAPORISATION.

All ponderable substances have an affinity for heat. When they combine with it they form elastic fluids or gases; therefore every gas is a combination of heat with a ponderable substance. The affinity of bodies for heat is various. Gases have the greatest affinity, and solid bodies the least, while fluids stand intermediate in that respect. Those bodies which have the greatest affinity for heat are, therefore, termed *volatile*, while those which have the least affinity are said to be *fixed*—*corpora volatilia* and *corpora fixa*. The stronger the affinity of the body for heat, the greater is the difficulty of depriving the body of its aeriform condition by pressure and cooling. The gas is therefore said to be *permanent*, such as oxygen, for instance, which has never been reduced to the liquid form. But those substances which are said to be non-permanent are designated *Vapors*. Their affinity for heat is so weak, that the

mere contact with a body cooler than themselves reduces them to a fluid. Then there is another class of substances which occupy an intermediate position to those mentioned, such as carbonic acid gas, which by strong pressure and cooling is reduced to the fluid state, and by still greater cooling, such as that produced by its own evaporation, it assumes the solid state.

The *elasticity* or *tension* of a gas or vapor implies the amount of heat which that gas or vapor contains; but in the same gas, and at the same temperature, the tension varies according to the density of the gas, the expansive force being in the direct ratio to that density.

Vapors contain much more heat than the fluids from which they are derived, while they occupy much more space. A cubic inch of water when expanded into steam occupies about a cubic foot. If it require a certain time to convert water from 32° F. up to 212° F., it will require a continuance of the same heat for five hours longer, to convert that water into vapor. But however violently the water be boiled, it does not rise to a higher degree of temperature than 212°, the additions of heat applied to it being consumed in converting the water into vapor.

If a thermometer is placed in this steam, it will indicate no higher temperature than 212°. What then has become of the heat which has been imparted to the water, for neither the steam nor the water indicates its presence? From the investigations of Dr. Black, Mr. Watt, and Lavoisier, it appears that as much heat disappears as is capable of raising the temperature of that portion of water which is converted into steam 1000 degrees, or it would raise 1000 times as much water by one degree. Dr. Black gives the latent heat of water at 960 degrees, Mr. Watt 940 degrees, and Lavoisier rather over 1000 degrees, and Gmelin 990 degrees.

Liquids are converted into vapor much more easily when in contact with rough and angular surfaces, than with those which are smooth. In glass vessels water boils at a temperature of two degrees higher than in metallic ones. If, therefore, a piece of iron be dropped into the water which has just begun to boil in a glass vessel, it immediately ceases to boil. But this only takes place when a permanent gas comes into play, because the mixture of watery vapor and gas sustains the pressure of the atmosphere at a temperature below 212° F. Pure boiled water evolves no bubbles of vapor on the introduction of platinum wire, although it boils up.

Many bodies cause an accumulation of heat in water, by which its temperature is raised much higher than the boiling-point. When this is attained, the water is apt to burst suddenly into vapor, when the temperature falls down to the boiling-point. This intermittent ebullition takes place when the water contains sulphate of potash in greater quantity than the water is enabled to dissolve. Also in sulphuric acid that contains a small quantity of sulphate of lead,

and in nitric acid containing crystals of nitrate of silver. The presence of fixed oil raises the boiling-point of water by several degrees. A stratum of volatile oil upon the surface of the water raises the temperature 10° above the boiling-point. The presence of metal filings, or clippings, prevents irregular ebullition, as the metallic points facilitate the formation of bubbles, but platinum is not so efficacious as iron or zinc, or those metals which decompose water.

If a volatile liquid be dropped on a plate of iron heated a little below redness, the liquid does not adhere to the iron, but accumulating in a globule, it runs over the iron with but little evaporation. The liquid does not become heated to its boiling-point, although vapor escapes from it, this vapor being evolved between the heated surface of the liquid and the plate. If the temperature of the plate is lowered to a certain degree, the liquid loses its spheroidal condition, and adheres to the plate, when it is evolved with great rapidity into vapor. The heated surface may be either platinum, silver, copper, iron, and other metals, or glass or porcelain, but the lower its conducting power the more strongly must it be heated. The liquid may be either sulphurous acid, ether, alcohol, water, and even sulphuric acid and mercury, but the higher the boiling-point of the liquid, the higher must the metal be heated. The cause of the phenomena manifested by liquids in the spheroidal state, is attributed to a layer of vapor between the liquid and the plate, by which they do not come in contact, and thus the transmission of heat by conduction is retarded.

Prof. Faraday has frozen mercury in a red-hot crucible of platinum, by putting ether into the crucible, and then solid carbonic acid, and when the whole is in the spheroidal condition, dipping into it a metallic spoon containing between 400 and 500 grains of mercury. The film of vapor which intervenes between the red-hot crucible and the liquid, prevents the communication of heat from the crucible to the mercury. Water has been frozen in the same manner in a red-hot platinum crucible by the agency of liquid sulphurous acid.

Water passes into the spheroidal state at any temperature above 340° F., but when it falls to 288° F. the water spreads upon the surface of the metal, and is quickly evolved into steam. Alcohol passes into the spheroidal state at 273° F., and ether at 142° F.

The temperature at which liquids boil is not fixed, like that of solids, but depends upon the degree of pressure to which that liquid is subject. In ordinary cases of boiling, the liquid is subject to the pressure of the atmosphere, which although 815 times lighter than water exerts a pressure upon the surface of the fluid of about fifteen pounds upon the square inch.

If a glass tube of sufficient length, closed at one end, be filled with mercury, and inverted in that liquid, the pressure of the air

will sustain that column of mercury to the height of 0·76 metres, or 29·92 inches. This is termed the *atmospheric pressure*. The space above the mercury is called the *Torricellian vacuum*. The column of mercury does not, however, remain stationary, but is almost constantly falling or rising, not through the expansion of the mercury through heat, as is the case with the thermometer tube, but through the varying pressure of the atmosphere, which varies within the limits of one-tenth of the whole pressure, and thus affects the boiling-point of water so much as $4\frac{1}{4}$ degrees. When the height of the mercurial column is indicated by the number in the first column of the following table, then the boiling-point of water is expressed by the numbers in the second column :

Inches of Mercury.	Water boils.
27·74.....	208° F.
28·29.....	209
28·84.....	210
29·41.....	211
29·92.....	212
30·6.....	213

Water, therefore, only boils at 212° F., when the barometer stands at 29·92 inches. If we ascend a mountain, and thus lessen the height of the column of air, the pressure becomes less, and the boiling-point of water is lowered. On the top of Mont Blanc water boils at 184° F.; but if we descend into the interior of the earth, the boiling-point is raised. An instrument has been constructed by which the height of mountains can be ascertained with great precision, by means of the boiling-point of water. A difference of one degree of temperature indicates an elevation of about 550 feet. If the pressure of liquids is reduced by the air-pump, liquids boil at considerably lower temperatures. If the exhaustion of air be thorough, liquids boil at a temperature 145° lower than their boiling-point in the air. Water will boil at 67°, when deprived of atmospheric pressure. If a flask containing boiling water be closed with a cork, the water soon ceases to boil in consequence of the pressure of the steam above the water; but if the flask be plunged in cold water, the boiling is renewed. This is occasioned by the condensation of the steam in the upper part of the flask, by which the pressure is removed, and the water thereby is allowed to boil at a much lower temperature. If, on the contrary, the flask be plunged into hot water, the boiling is instantly checked, for then the steam, not coming in contact with a cold surface, and thereby becoming condensed, accumulates, and by its pressure retards the ebullition. In a *Papin's Digester*, which confines the steam, and thus causes a great pressure upon the water, that fluid does not boil when heated up to 400°.

Liquids which are injured by the application of heat so high as 212°, are now boiled in a vacuum. If the air and steam is passed off the surface of the heated liquid, it may be boiled at a temperature of 150°.

Vegetable infusions are now reduced to an extract by the same means, and thus those more volatile portions which would be dissipated at a heat of 212° , are retained unimpaired in the extract.

The temperatures at which different liquids begin to boil is various; but *cæteris paribus*, the boiling temperature for each particular liquid is constant. The boiling-point of the following liquids has been determined with great accuracy:

	Boiling-Point
Hydrochloric Ether.....	52° F.
Ether.....	96°
Sulphide of Carbon.....	118°
Ammonia (sp. gr. 0.945).....	140°
Alcohol.....	173°
Water.....	212°
Nitric Acid (sp. gr. 1.42).....	248°
Crys. Chloride Calcium.....	302°
Oil of Turpentine.....	314°
Naphtha.....	320°
Phosphorus.....	554°
Sulphuric Acid (sp. gr. 1.843).....	620°
Whale Oil.....	630°
Mercury.....	662°

Water which, when pure, boils at 212° , exhibits a much higher boiling-point when there is added to it salts, or sulphuric acid, phosphoric acid, and other less volatile substances. Water saturated with common salt (100 water to 30 salt) boils at 224° ; if saturated with nitrate of potash (100 water to 74 of the salt) boils at 238° ; but if saturated, when cold, with chloride of calcium, it rises to 264° before it boils. The boiling-point of alcohol is raised by mixing it with water, and that of ether by the addition of alcohol. In like manner, permanent gases combined with water and other liquids, require an elevation of temperature, or a diminution of pressure, to make them escape. The escape of the gas appears to take place in the vicinity of hard or angular surfaces, and never from the interior of the liquid, as if the contact of a solid body were necessary to the elimination of the gas.

When steam is confined, it increases in temperature, and acquires great force. If the steam of boiling water condense upon the skin it causes scalding; but if the steam is subject to great pressure, and allowed to issue from an orifice upon the hand, it does not scald it; in fact, the temperature is below that of boiling water; for the sudden expansion of the confined vapor abstracts sufficient heat from the other portion to reduce its temperature down to 120° . The air which becomes mixed with the steam prevents it from collapsing, as it is then converted into low-pressure steam.

When steam is heated by itself, it is not capable of expanding more than any other aeriform body; for it may be heated until the vessel which contains it is red-hot, without exerting any great elastic force; but if water be present, then fresh quantities of steam

are added to that already accumulated, and which add their force to the other, until the pressure becomes almost irresistible. The following table gives the pressure of steam up to 50 atmospheres, and is the most correct and reliable series of experiments upon this subject which we have. It is the result of the labors of a commission of the French Academy, consisting of MM. Dulong and Arago:

Elasticity of Steam, taking Atmospheric Pressure as Unity.	Temperature.	Elasticity of Steam, taking Atmospheric Pressure as Unity.	Temperature.
1	212° F.	13	386° 66' F.
1½	233.96	14	386.94
2	250.52	15	392.46
2½	263.84	16	398.48
3	275.18	17	403.82
3½	285.08	18	408.92
4	293.72	19	413.78
4½	300.28	20	418.46
5	307.5	21	422.96
5½	314.24	22	427.28
6	320.36	23	431.42
6½	326.26	24	435.56
7	331.20	25	439.34
7½	336.50	30	457.16
8	341.78	35	472.73
9	350.78	40	486.59
10	358.28	45	499.14
11	366.85	50	510.60
12	374.00		

The Absorption of Heat.—In the formation of gases and vapor, as in liquefaction, the heat which enters into these substances becomes latent, or is insensible to the feelings and the thermometer. The same substance, whether it vaporises slowly or quickly, absorbs the same amount of heat. Solid carbonic acid produces, in vacuo, when the temperature of the apartment is at 30° C., a cold —933° C. If solid carbonic acid is mixed to a paste with alcohol, it produces a cold of —92°, and with ether, —99°. The sulphide of carbon placed on a rag which is wrapped around a thermometer, lowers it in vacuo from +16° to —72°. Liquid sulphurous acid produces in vacuo a temperature of —61°. A quantity of mercury placed in vacuo, with an equal weight of liquid sulphurous acid, is frozen in five minutes. Water placed in vacuo, in the presence of strong sulphuric acid to absorb the vapor as it forms, is quickly frozen. If a thermometer is surrounded with cotton moistened with various liquids in vacuo, the temperature is indicated as —41.25° with water; with sulphuric ether, —51°; with alcohol, 37.5°; with nitric ether, 31.25°; and with hydrochloric ether, —30°. Graham, in the same manner, obtained with water a temperature of —14°, and with alcohol—or with three parts of alcohol with one of water—a temperature of —31°.

Wollaston's Cryophorous is a glass tube with a bulb blown on each end of it. This tube and bulbs are exhausted of air and con-

tain a small portion of water. If while this water is in one of the bulbs, the other which is empty be immersed in a freezing mixture, the water in the other bulb is frozen. This is occasioned by the rapid evaporation of the water in the bulb, while the vapor is condensed in the other or cooled bulb.

When liquid carbonic acid is allowed to issue from a small orifice from the vessel in which it is confined, and the vaporising acid be caught in a hollow vessel, the latter soon becomes coated with solid carbonic acid in the form of frost or snow, the temperature in the mean time sinking to -100° . If the liquid carbonic acid is confined in a tube with a stop-cock, when the acid is passing out, that within the tube manifests a violent motion, and about one-eighth of the acid is soon frozen into a porous mass. The temperature also falls to -65° .

The *Psychrometer* of Auguste, is for the purpose of determining the hygrometric state of the air. Two small thermometers are placed near each other, while one of them is covered with wet muslin. Its temperature becomes lower than the one containing nothing upon its bulb, in proportion as the air is dryer, or as the evaporation progresses more rapidly. The difference in the temperature of the two thermometers being multiplied by 2, and the product subtracted from the temperature denoted by the bare bulb, the remainder indicates the temperature at which the aqueous vapor in the air will condense.

If the bulb of a thin glass tube be covered with cotton wet with ether, and a strong current of air be thrown upon it, the water within the bulb will soon be frozen. Or if the bulb be inclosed in cotton soaked with liquid sulphurous acid, and a stream of air be thrown upon it, mercury within that bulb will be quickly frozen. The temperature in this instance falls to -36° . Or, if half an ounce of mercury be placed in a shallow dish, such as a watch-glass, and liquid sulphurous acid be poured upon it, the mercury is soon frozen if a stream of air from a pair of bellows be directed upon it.

Solid carbonic acid, when air is blown upon it, produces cold amounting to -72.2° . If it is mixed with ether, the cold produced is 76.7° . If mercury be placed in solid carbonic acid in the air, it quickly freezes, and still more quickly, or instantly, if ether is mixed with the acid.

The addition of heat to a boiling fluid does not raise its temperature any higher, for the heat which is added is only expended in the formation of vapor by which it becomes latent. The vapor remains at the temperature of the boiling body, provided no more heat be subsequently added to it. This subject of the causes of the variations in the temperature of a body heated to the boiling-point, has already been adverted to.

Sublimation and *Distillation* depend upon the conversion of a body into vapor, and which is afterwards condensed into a fluid or

solid. In these cases a substance which is easily volatilised is separated from one which is less volatile, the latter generally remaining behind as the residue, called by the old chemists the *Caput Mortuum*, or if liquid, the *Phlegma*. If the vapor condenses into a solid, then the operation is designated *Sublimation*; if liquid, *Distillation* is the term applied to it. The product in the former case is called the *sublimate*, in the latter the *distillate*. When the distillate is subject to a second distillation, it is said to be *Rectified*. *Cohobation* means, that the distilled product has been returned to the alembic or retort, and having been poured upon what remains behind, or on fresh material, is re-distilled.

When a substance has a stronger affinity for a gas than has the heat it contains, then a combination of the two substances takes place, and the latent heat of the gas, or gases (if both be gaseous bodies), is liberated, and is rendered sensible, provided, however, that the newly formed compound is not itself a gas. This is illustrated by the condensation of oxygen and hydrogen gases by combination into a fluid. The combination of oxygen with the following substances, also illustrates it, viz., boron, phosphorus, selenium, iodine, and metals. Also of acid gases by ammoniacal gas and by many other salifiable bases; also of all gases by water, alcohol, and other liquids; of aqueous vapor by acids, salifiable bases, salts, and other bodies; of alcohol and ether vapors by water, sulphuric acid, fat oil, camphor, &c.

When steam at 212° comes in contact with citric acid, or with pulverised salts, hydrate of potash, or with sugar, part of the water is absorbed and they are dissolved, the temperature of the solution being several degrees above 212° , or is about that at which the aqueous solutions of these substances boil. Alcohol vapor, at a temperature of 83.3° , raises that of chloride of calcium to 99° . (Faraday.)

According to Pouillet, the degrees of incandescence stand as follows: Incipient redness is 525° . Dull redness, 700° . Cherry redness at the commencement, 800° ; still brighter, at 900° ; and full redness at 1100° . Dark yellowish red, at 1200° . Bright ignition, at 1300° . White heat, at 1400° . Strong white heat at 1500° , and dazzling white heat at 1600° .

The following tables exhibit the melting-point of a number of substances as indicated by the thermometers of Fahrenheit and the Centigrade, and the pyrometers of Wedgewood and Daniell:

MELTING-POINTS.

	Cent.	Fah.		Cent.	Fah.
Carbonic acid,	-65°	-85°	Phosphorus, -	+ 45°	+ 113°
Ether, - - -	-44	-47.2	Potassium, -	+ 58	+ 136.4
Mercury, - -	-40.5	-40.9	Wax, - - -	+ 67	+ 152.6
Oil of vitriol,	-25	-13	Sodium, - -	+ 90	+ 194
Bromine, - -	-20	- 4	Iodine, - -	+ 107	+ 224.6
Prussic acid, -	-15	+ 5	Sulphur, - -	+ 109	+ 228.2
Water, - - -	0	+ 32	Camphor, - -	+ 175	+ 347

Disengagement and Absorption of Heat.—The most striking instances of the development of heat is furnished by oxygen during its combination with other bodies. The substance which eliminates heat after oxygen in combining with other bodies is chlorine; then follow bromine and iodine, and then selenium, sulphur, and phosphorus. The combination of strong acids with strong salifiable bases, and that of strong acids and strong bases with water, produce considerable heat. In all these cases, the bodies must have a strong affinity for each other, and are decidedly opposite in chemical nature.

The heat produced during the combination of oxygen with other bodies, is not satisfactorily accounted for. Gmelin thinks that the heat evolved may be a kind of heat different from heat of fluidity, producing no particular state of aggregation, but existing in a state of more intimate chemical combination with the ponderable matter, and set free when one ponderable substance combines with another. Or else, that the heat is formed at the moment of combination, by the union of the positive electricity of the one body with the negative electricity of the other.

Cold is produced principally when bodies combine chemically and pass into the liquid state. These combinations possess feeble affinities, the quantity of heat developed being not sufficient to produce liquidity, in which case heat is absorbed and rendered latent for that purpose.

These combinations are therefore termed *Freezing Mixtures*, and are produced by the solution of various salts in water and dilute acids, and by mixing these salts, and certain acids, or crystallised potash, or alcohol, with ice or snow. Those salts which contain water of crystallisation should not be deprived of it, for upon being mixed with water they will in that case produce heat instead of cold. The substances should be finely powdered, and mixed quickly, in large quantity, to produce the full effect, while the vessel in which the mixture is made should be a poor conductor of heat. When the greatest degree of cold is to be produced, the materials should previously be cooled, and then mixed. One part of water and one part of nitrate of ammonia lowers the temperature from $+10^{\circ}$ to -16° . Equal parts of sal ammoniac and nitre lowers the temperature from $+10^{\circ}$ to -12° . One part nitrate ammonia and one part carbonate soda from 10° to -14° . With three parts of sal ammoniac, one part of nitre, and six parts chloride calcium from $+25^{\circ}$ to -6° . Three parts sal ammoniac, five of nitre, and eight parts of Glauber's salt from $+10^{\circ}$ to -16° .

When one part of a salt is dissolved in four parts of water, the fall of temperature is as follows: sal ammoniac, 15.19° ; nitrate ammonia, 14° ; sulphate of potash, 2.9° ; chloride potassium, 11.81° ; nitre, 10.6° ; Glauber's salt, 8.1° ; common salt, 2.1° ; nitrate of soda, 9.46° ; chloride of barium, 4.5° ; nitrate of baryta, 2.1° ; sul-

phate of magnesia, 4.5° ; sulphate of zinc, 3.1° ; nitrate of lead, 1.9° ; sulphate of copper, 2.27° . If one part of a salt be dissolved in four parts of a saturated solution of another salt, the following degrees of cold are produced: sal ammoniac in solution of common salt, 8.4 ; in solution of nitre, 12.6° ; nitre in solution of sal ammoniac, 9.75° ; in solution of common salt, 9.4° ; of nitrate of soda, 7.06° ; of nitrate of baryta, 9.75° ; of nitrate of lead, 9.5° ; Glauber's salt in solution of common salt, 4.75° ; common salt in solution of sulphate of copper, 4.1° ; nitrate of soda in solution of sal ammoniac, 9.1° ; of nitre, 9.2° ; of common salt, 7.81° ; of chloride of barium, 2.75° ; of nitrate of lead, 8° ; nitrate of baryta in solution of nitre, 0.75° ; sulphate of zinc in solution of sulphate of potash, 1.75° ; sulphate of copper in solution of common salt, 4.9° . The following salts, on the contrary, produce rise of temperature: common salt in solution of sal ammoniac, 4.56° ; in solution of Glauber's salt, 1.75° ; of nitre, 0.75° ; of nitrate of soda, 3.8° ; chloride of barium in solution of nitrate of soda, 0.64° . Three parts of crystallised neutral carbonate of soda dissolved in ten parts of water produce a lowering of temperature amounting to 8.9° ; whilst three parts of the same salt in the anhydrous state, dissolved in ten parts of water, cause a rise of temperature of 12.2° ; 8 parts of crystallised Glauber's salt with 10 parts of water produce a fall of 6.7° ; on the contrary, 3 parts of dry Glauber's salt with 10 of water cause a rise of 2.2° ; 3 parts of crystallised sulphate of magnesia with 10 of water produce a fall of 3.1° ; and 3 parts of protosulphate of iron with 10 parts of water also produce a fall of temperature amounting 3.1° .

One part of a mixture of 50 parts of oil of vitriol, and 55 of water mixed with $1\frac{1}{4}$ part of Glauber's salt, cools from $+10^{\circ}$ to -8° . One part of dilute hydrochloric acid with $1\frac{3}{4}$ Glauber's salt, from -10° to -17.8° . One part of dilute nitric acid gives the following reductions of temperature: with 1 sal ammoniac, $\frac{1}{2}$ nitre, $1\frac{1}{4}$ Glauber's salt, from $+10^{\circ}$ to -12° . With $1\frac{1}{4}$ nitrate ammonia and $2\frac{1}{4}$ phosphate soda, from $+10^{\circ}$ to -6° . With $2\frac{1}{4}$ phosphate of soda, from $+10^{\circ}$ to -11° ; and with $1\frac{1}{4}$ Glauber's salt, from $+10^{\circ}$ to -16° . (Walker.)

Six parts of sulphuric acid produce with 6 parts of snow, heat; with 8 parts of snow, neither heat nor cold; but with a large quantity of snow, intense cold.

One part of snow, or pounded ice, produces the following fall of temperature. With $\frac{1}{2}$ dilute sulphuric acid (4 oil of vitriol to 1 water), from 0° to -32.5° . With dilute sulphuric acid, from -7° to -51° . With $\frac{1}{2}$ dilute nitric acid, from -23° to -49° . With 1 dilute nitric acid, from -17.8° to -43° . With $1\frac{1}{4}$ crystallised potash, from 0° to -28° . With $\frac{1}{2}$ common salt, from 17.8° to -20.5° . With 1 common salt, from 0° to -17.8° . With $1\frac{1}{2}$ common salt and $\frac{1}{2}$ nitrate ammonia, from -27.8° to -31.7° . With

$\frac{1}{2}$ chloride calcium, from -9° to -42.5° . With $1\frac{1}{2}$ chloride calcium, from 0° to -49° . With $1\frac{1}{2}$ chloride calcium, from 0° to -27.8° , and from -7° to -47° . With 2 chloride of calcium, from -17.8° to -54.4° ; and with 3 chloride calcium, from -40° to -58° ; and with absolute alcohol (Tralles), from 0° to -36.9° ; and with highly rectified spirits, from 0° to -80° .

If solid amalgam of lead is mixed with solid amalgam of bismuth, they will become liquid, and there will be a reduction of temperature amounting to 22° . If 204 parts of lead amalgam (103 lead to 101 mercury) be mixed with 172 parts of bismuth amalgam (71 of bismuth + 101 mercury), the temperature will be reduced from $+20^{\circ}$ to -1° . If to this mixture there are added 202 parts of mercury, the temperature is reduced to -8° . When a finely divided mixture of 59 tin, 103.5 lead, and 182 bismuth is dissolved in 808 parts of mercury, the temperature falls from $+17.5^{\circ}$ to -10° . (Gmelin.)

When porous bodies absorb any liquid by capillary attraction, and no chemical action takes place, there is a rise of temperature of from $\frac{1}{2}$ to $\frac{1}{2}$ degree with inorganic bodies, and, with organic bodies, from between 1° and 10° .

Whenever a body is compressed or condensed, there is an evolution of heat; while expansion, on the contrary, is attended with an absorption of heat. In the former case, the development of heat is probably occasioned by the decreased capacity of the condensed body for specific heat. If the air is suddenly compressed, there is sufficient evolution of heat to set tinder on fire. If the condensed body be oxygen gas, then paper and wood may be ignited by its compression. Oiled paper can likewise be ignited by the compression of chlorine gas. Fulminating silver can be ignited by the compression of hydrogen, nitrogen, and carbonic acid gas. If, on the contrary, air is suddenly expanded under the receiver of the air-pump, cold is produced, as may be exemplified by Breguet's thermoscope.

By hammering, metals become quite hot and condensed. An alloy of 1 part of iron and 2 parts of antimony, gives sparks when filed. On a revolving grindstone $7\frac{1}{2}$ feet in diameter, an iron nail becomes white-hot in 15 seconds, a brass rod in 30 seconds, while a glass tube becomes red-hot, melts, and flies off. Agate, on the same grindstone, gives off sparks of fire, while the stone itself becomes red-hot.

Two pieces of wood, when rubbed briskly together, catch on fire. This mode of kindling fire is frequently resorted to by the aborigines of this country.

INFLUENCE OF HEAT ON CHEMICAL COMBINATION AND DECOMPOSITION.

Water can be resolved into its constituent gases by the agency of incandescent platinum. For this purpose a platinum wire is

sealed into the closed extremity of a tube-retort, having its neck removed just above the wire. The tube is filled with pure water, and the current of a voltaic battery is passed through the wire. The incandescent wire forms round itself an atmosphere of vapor, which is decomposed. If a button of platinum wire is fully ignited by the oxy-hydrogen blowpipe, and then immersed in water heated up nearly to 212° , bubbles of mixed gases ascend, and may be collected. Instead of platinum, buttons of iridium, osmium, and palladium may be substituted.

THE NATURE OF HEAT.

It is convenient to adopt the material theory of heat in considering its accumulation in bodies, and in expressing quantities of heat, and the relative capacities of bodies for heat. Indeed, every thing relating to the absorption of heat suggests the idea of its substantial existence; for heat, unlike light, is never extinguished when it falls upon a body, but is either reflected, and may be further traced, or is absorbed and accumulated in the body, and may again be derived from it without loss. But the mechanical phenomena of heat, which resemble those of light, may be explained with equal, if not greater, advantage, by assuming an undulatory theory of heat, corresponding with the undulatory theory of light. A peculiar imponderable medium or ether is supposed to pervade all space, through which undulations are propagated that produce the impression of heat. A hot, radiant body is a body possessing the faculty to originate or excite such undulations in the ether, or medium of heat, which spread on all sides around it, like the waves from a pebble thrown into still water. Sound is propagated by waves in this manner, but the medium in which they are generally produced, or the usual vehicle of sound, is the air; and all the experiments of the reflection and concentration of heat, by concave reflectors, may be imitated by means of sound. Thus, if a watch, instead of the lamp, be placed in the focus of one of a pair of conjugate reflecting mirrors, the waves of air occasioned by its beating emanate from the focus, strike against the mirror, and are reflected from it, so as to break upon the face of the opposite mirror, are concentrated into its focus, and communicate the impression of sound to an ear placed there to receive it. The transmission of heat from the focus of one mirror to the focus of the other, may easily be conceived to be the propagation of similar undulations through another and different medium from air, but co-existing in the same space. In adopting the material theory of heat, we are under the necessity of assuming that there are different kinds of heat, some of which are capable of passing through glass, such as the heat of the sun; while others, such as that radiating from the hand, are entirely intercepted by glass. But, on the undulatory theory, the different properties of heat are referred to differ-

ences in the size of the waves, as the differences of color are accounted for in light. Heat of the higher degrees of intensity admits of a kind of degradation, or conversion into heat of lower intensity, to which we have nothing parallel in the case of light. Thus, when the calorific rays of the sun, which are of the highest intensity, pass through glass, and strike a black wall, they are absorbed, and appear immediately afterwards radiating from the heated wall, as heat of low intensity, and are no longer capable of passing through glass. It is yet an unsolved problem to reverse the order of this change, and convert heat of low into heat of high intensity. The same degradation of heat, or loss of intensity, is observed in condensing steam in distillation. The whole heat of the steam, both latent and sensible, is transferred without loss, in that process, to perhaps fifteen times as much condensing water; but the intensity of the heat is reduced from 212° to perhaps 100° F. The heat is not lost, for the fifteen parts of water at 100° are capable of melting as much ice as the original steam. But by no quantity of this heat at 100° can temperature be raised above that degree: no means are known of giving it intensity.

If heat of low is ever changed into heat of high intensity, it is in the compression of gaseous bodies by mechanical means. Let steam of half the tension of atmosphere, produced at 180° , in space otherwise vacant, be reduced into half its volume, by doubling the pressure upon it, and its temperature will rise to 212° . If the pressure be again doubled, the temperature will become 250° , and the whole latent heat of the steam will possess that high intensity. When air itself is rapidly compressed in a common syringe, we have a remarkable conversion of heat of low into heat of very high intensity. It may be imagined that the elevation of temperature produced by the friction of hard bodies has a similar origin; that it results from conversion of heat of low intensity which the bodies rubbed together possess, into heat of high intensity. But it would be necessary further to suppose that a supply of heat of low intensity to the bodies rubbed can be endlessly kept up, by conduction or radiation, from contiguous bodies, as there is certainly no limit to the production of heat by means of friction. Count Rumford, by boring a cylinder of cast-iron, raised the temperature of several pounds of cold water to the boiling-point. Sir H. Davy succeeded in melting two pieces of ice in the vacuum of an air-pump, by making them rub against each other, while the temperature of the air-pump itself and the surrounding atmosphere was below 32° . M. Haldot observed that when the surface of the rubber was rough, only half as much heat appeared as when the rubber was smooth. When the pressure of the rubber was quadrupled, the proportion of heat evolved was increased sevenfold. When the rubbing apparatus was surrounded by bad conductors of heat, or by non-conductors of electricity, the quantity of heat evolved was diminished. Ac-

According to Pictet, a piece of brass, rubbed with a piece of cedar-wood, produced more heat than when rubbed with another piece of metal; and the heat was still greater when two pieces of wood were rubbed together. He also finds that solids alone produce heat by friction; no heat appears to arise from the friction of one liquid upon another liquid, or upon a solid, nor by the friction of a current of air or gas upon a liquid or solid. One other point connected with the nature of heat remains, to which there is at present occasion to allude—the existence of a repulsive property in heat. Such a repulsive power in heated bodies is inferred to exist from the appearance of extreme mobility which many fine powders assume, such as precipitated silica, on being heated nearly to redness. Professor Forbes also to such a repulsion attributes the vibrations which take place between metals unequally heated, and the production of tones, to which allusion has already been made. But this repulsive power was rendered conspicuous, and even measurable, by Dr. Baden Powell, in the case of glass lenses, of very slight convexity, pressed together. On the application of heat, a separation of the glasses, through extremely small but finite spaces, was indicated by change in the tints which appear between the lenses, and which depend upon the thickness of the included plate of air. This repulsion between heated surfaces appears to be promoted by whatever tends to the more rapid communication of heat. (Graham.)

ELECTRICITY.

ELECTRICITY IN ITS PHYSICAL RELATIONS; OR, THE PHYSICS OF ELECTRICITY.

THAT department of Electricity designated *Mechanical* or *Frictional Electricity*, will properly come under the division of Physics of Electricity, while that termed *Voltaic* or *Galvanic Electricity*, belongs more properly to the Chemistry of Electricity. Of Frictional Electricity we shall be necessitated in a work like this, to consult brevity, as the other department of this science, on account of its great importance and length, will claim our principal attention.

That electricity developed by the common electrical machine, is called *Mechanical* or *Frictional Electricity*, in consequence of the manner by which it is obtained. This electricity presents itself as that fluid in its highest state of intensity, while the electricity developed by chemical action, possesses but little intensity compared with its quantity. Frictional electricity exhibits itself as that fluid in a state of rest, and hence the designation of *Static Electricity* in contradistinction to the voltaic, which is known as *Dynamic Electricity*.

The great development of electricity during the escape of steam, may with propriety come under the head of frictional electricity, for its development appears to proceed from the friction of the particles of steam against the sides of the orifice from whence it is issuing. The electricity from this source is possessed of great intensity, and affords sparks which readily pass through considerable intervals of air, and charge a leyden jar almost instantaneously. This electricity is that designated *Positive*, and cannot be obtained unless there is a strong pressure of steam, so as to issue from the orifice as a transparent vapor.

Electricity is considered as existing in two states, or as consisting as two entities, which are termed *Positive* and *Negative Electricity*. They are imponderable, and diffuse themselves uniformly and with great rapidity through those substances through which they are able to penetrate. Electricity travels through a wire with great velocity, some maintaining that it traverses the wire with the velocity of light through

the planetary space, while others contend that its progress is only 2,500 miles a second.*

To ascertain the conducting power of metals, an instrument has been used which determines it by passing the current of a constant battery through the instrument, which measures its magnifying power. At the same time a collateral circuit is opened to the same current through a certain length of fine wire, first of one metal and then of another. In the following table, the conducting power of the metals is, of course, in proportion to their reduction of the magnetising power of the collateral current. Therefore the alloy of silver, in the proportion in which it exists in coin, is the best conductor, while platinum is the poorest.

	Magnetising power.	Reduction.
Silver Coin,.....	7350 grn.	17050 grn.
Copper,.....	8180 "	16220 "
Pure Silver,.....	8800 "	15600 "
Brass,.....	12046 "	12354 "
Gold Coin,.....	12820 "	11580 "
Iron,.....	16600 "	7800 "
Platinum,.....	17010 "	7390 "

For a very extended list of the best and poorest conductors, the student is referred to Gmelin's Chemistry, vol. i. p. 810, et seq.

GALVANIC OR VOLTAIC ELECTRICITY.

That form of electricity which is developed by chemical action, is termed *Galvanic* or *Voltaic Electricity*, designations which arose from the names of Galvani and Volta, the two discoverers of chemical electricity.

When two metals are placed in contact with each other, and are immersed in a liquid which acts with more energy upon one of them than upon the other, there quickly ensues the developement of a current of electricity, termed *Positive* electricity, or of two currents, termed *Positive* and *Negative Electricity*. The two metals used for this purpose must bear a peculiar relation to each other. The conditions necessary are, that one of the metals shall have a stronger affinity for the acid of the fluid than the other, or in other words, that one of the metals shall be acted upon with more energy by the acid than the other. Copper and zinc, or platinum and zinc, are the metals generally used, the latter metal being the positive one, or that acted upon with most energy by the acid.

It is supposed that the electrical current is developed at the zinc plate, and passing through the fluid to the copper plate, it passes

* Gmelin informs us that electricity traverses a wire "faster than light moves in the celestial spaces," while the late experiments of Prof. Airy make its velocity only about 2,500 miles each second of time.

up the wire connected with the copper plate, and down the wire in contact with the zinc plate, to the plate itself. Thus the current is supposed to pass from the zinc to the copper within the battery, and from the copper to the zinc without it. The zinc plate is therefore termed the *positive plate*, as it is the one acted upon, and the copper plate is recognised as the *negative plate*, while the wire attached to the negative or copper plate is termed the *positive* or *delivering* pole, and that to the zinc or positive plate, the *negative* or *receiving* pole.

The nomenclature of Prof. Faraday is generally recognised by electricians. The poles are termed electrodes, from two Greek words signifying ways or paths of electricity. The positive pole he designates the *Anode*, while the negative is the *Cathode*; but the terms *positive* and *negative* are generally made use of.

It is not necessary that two dissimilar metals should be used in order to obtain a voltaic current, but one metal in a dissimilar state may be substituted. If one portion of the metal is more dense than the other, a current is developed in that portion of the metal which is the softest, as that portion is acted upon more energetically by the acid than the other. In that case the harder portion is acted upon by the acid with less energy than if it were placed alone in the acid, the action upon the less dense portion appearing to retard that upon the harder portion. Or, if a different amount of surface of metal be exposed to the action of the acid, there will be developed a current of electricity which passes from the greater surface, or that acted most upon, to that acted least upon.

The galvanic battery possesses also intensity and quantity. By increasing the surface of the plates there is an increase of quantity, by which the developement of heat and magnetism is increased, although the power to decompose substances, or to give shocks, is but slightly increased. These species of batteries are termed *calorimeters*, in consequence of their producing intense heat. A calorimeter can be constructed by connecting all the zinc plates of a battery, by which they act as if composed of one large plate. Or two large sheets of zinc and copper may be coiled concentrically upon themselves, with a rope of horse-hair laid between to insulate them. These plates are immersed in dilute sulphuric acid. In order to obtain intensity the plates are connected together consecutively, that is, by connecting the copper plate of each pair with the zinc plate of the next one. Here the electricity traverses through a series of pairs, these pairs being separated from each other by a stratum of acid, or some other imperfectly conducting liquid. By this means, that condition of the electrical fluid termed *intensity* is obtained. It passes more readily through imperfect conductors. It gives shocks and decomposes compounds with greater facility than that termed *quantity*. When the plates are increased to several hundred, the intensity of the electricity then resembles that from

the electrical machine in its power of passing through intervals of air, and in the manifestation of all the phenomena characteristic of frictional electricity. For all these purposes where electro-magnetic apparatus is required, electricity of low intensity must be used on account of its easy insulation, while at the same time its power of producing magnetism is much greater than electricity of high tension. Batteries, therefore, of great intensity are not calculated for electro-magnetic apparatus. No greater number than six of Grove's cups should be used for this purpose, while three may answer every purpose.

THE VARIOUS FORMS OF BATTERIES.

The *Trough Battery* may be regarded as a representative of the first batteries used. It consists of a series of plates of copper and zinc which are placed side and side alternately. Sometimes the zinc plates are inclosed in copper cases open both at the top and the bottom. The plates are lowered into the acid by a mechanical contrivance, such as a windlass, &c. As soon as they are immersed in the acid solution (composed of one part of sulphuric acid to forty or fifty parts of water), the developement of electricity commences. If the zinc plates and copper plates are arranged consecutively, then intensity is attained; but if all the zincs are connected with each other, and the copper plates are likewise connected together, then the battery is converted into a *calorimeter*. Or in the former instance we have the manifestation of *intensity*, in the latter that of *quantity*. *Cruikshank's Battery* is an instance of the trough battery, although its mechanical arrangement is often varied to suit the convenience of the operator. These batteries, for instance, are often arranged to swing upon a pivot, so that merely inverting the trough conveys the acid from the zincs, as devised originally by Professor Hare. Several of these batteries so fixed as to swing together, forming the arrangement of Professor Locke, are termed by him the *Organized battery*.

Smee's Battery.—This battery consists of a glass case of a spheroidal shape, in which is suspended a pocket of baked earthenware. In this pocket is placed a little mercury, and then a piece of zinc is laid within it, with its lower end in contact with the mercury. A strip of copper is inserted down between the zinc and the pocket, until its end terminates in the mercury, by which a perfect contact is attained between the zinc and the copper strip. At the other end of the copper there is soldered a strip of platinum, which falls into the next glass cup. The copper strip is covered with a solution of gutta serena to prevent the acid acting upon it, otherwise, besides the action, the copper would be transferred to the platinum strip. The solution with which this battery is charged is a mixture of one part of sulphuric acid to eight or ten parts of water.

If the zinc plates are not amalgamated there will ensue a local action, or the acid will act upon the zinc, with the development of hydrogen gas. The mercury prevents the local action, so that when the poles are not in contact, or the current not closed, there will be no action of the acid upon the zinc. The power gained by increasing the size of this battery is so little, that it would be no object gained in increasing it.

The action of this battery may be thus stated: the water undergoes decomposition, one equivalent or atom of its oxygen uniting with the zinc, forming the oxide of zinc, with which the sulphuric acid combines to form the sulphate of zinc. The hydrogen atom of the water is given off at the negative or platinum plate.

It will be perceived that the oxygen and hydrogen are given off, the former at the zinc plate, while the latter is evolved at the copper or platinum plate. It is not supposed that these elements travel through the fluid, but that the two atoms of water in contact with the plates are simultaneously decomposed, and that a chain of decomposition is established between these atoms. By an inspection of Fig. 27 this will be illustrated, where the oxygen atom (1) of the

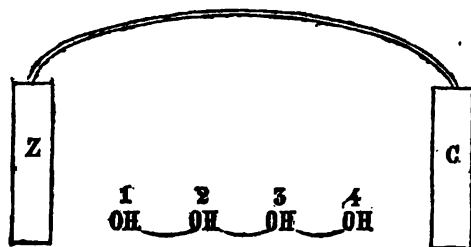


Fig. 27.

water unites with the zinc, the hydrogen simultaneously unites with the oxygen of No. 2, releasing its hydrogen, which unites with the oxygen of No. 3, and releasing its hydrogen, which atom uniting with the oxygen of No 4 releases the last hydrogen atom, which having nothing to combine with passes off at that plate. The subject of electro-decomposition will be spoken of in connection with the electrolyte.

The Sulphate of Copper Battery.—This battery is made in the form of a double cylinder of copper, with a bottom of the same metal. This copper vessel, while containing the liquid which acts on the zinc, answers the purpose of the negative plate. A solution of sulphate of copper, consisting of two ounces of that salt to one pint of water, is placed in the space between the two copper cylinders. A cylinder of zinc is immersed in this solution, but only when the battery is to be put into action. This zinc cylinder rests

upon the exterior copper one, by the interposition of some non-conducting substance, such as dry wood or ivory.

These batteries are not very permanent, as their action does not last longer than half an hour. The action of these batteries is as follows: The water is decomposed, its oxygen combining with the zinc, whereby an oxide of that metal is produced. At the same time the copper salt is decomposed, and its acid combines with the oxide of zinc, forming the sulphate of zinc, which remains in solution. The oxide of copper being now released from its combination with the sulphuric acid, partly adheres to the zinc cylinder, while another portion falls to the bottom as a black deposit, part of which is the reduced metal. The hydrogen of the water decomposes the oxide of copper, forming with it water. It is thus that the reduced metal is formed, while but little gas is given off, as it is consumed in the reduction of the metal. These batteries have, therefore, received the designation of "*Hydrogen Consuming Batteries*."

These batteries have greater intensity in proportion to the quantity, than Smee's. This is accounted for from the fact, that in these batteries the final decomposition falls on the oxide of copper instead of water, the latter requiring a greater expenditure of electrical force in order to decompose it than the former. The force of a galvanic battery depends upon the amount of corrosive force of the solution, minus the force of chemical affinity which has to be overcome in the decompositions which attend its action.

The Constant Battery.—In this battery there is a greater advance towards perfection. In the former battery it will be remembered that the zinc cylinder soon becomes coated with the pulverulent copper deposit, which speedily retards its action, and finally terminates it. If the sulphate of copper only is in contact with the copper plate, it supplies the oxide of that metal for the purpose of the final decomposition instead of the water, with as great facility as if it were in contact with the zinc. If, therefore, a cell of some porous substance is interposed between the copper and the zinc, there are formed two cells, the outer one of which is filled with solution of sulphate of copper, while the inner one contains a solution of sulphate of soda. The porous partition prevents the sulphate of copper from passing into that cell in which the zinc is contained, and therefore it escapes being coated with the copper deposit. The porous cell may be constructed of leather, or of baked earthenware, but the latter should not be glazed.

The action of this battery may be expressed as follows: The water is decomposed, its oxygen combining with the zinc and producing the oxide. The hydrogen of the water then decomposes the sulphate salt, by forming water with the oxygen of its oxide. The sulphuric acid thus liberated passes through the porous partition, and there furnishes a constant supply of acid to combine with the oxide of zinc to form the sulphate of that metal.

This battery will maintain a constant action for several days, but the solution of sulphate of copper must be kept saturated by adding occasionally a little of that salt to it. From the constancy of this battery, it is used extensively in electrotyping.

Grove's Battery.—In the preceding battery, the hydrogen from the decomposition of the water, is consumed in the decomposition of the oxide of copper, with which it unites to form water. Hence the designation of *Hydrogen Consuming* batteries. In the present battery, that of Grove, a farther advance towards perfection is made. In the sulphate of copper battery the chemical combination which has to be disrupted is that of oxygen from the metal copper; or its force may be stated as equal to the affinity of oxygen for zinc, minus the affinity of oxygen for copper. Strong nitric acid is supplied instead of the sulphate of copper in Grove's battery, as in that case the affinity to be overcome is in favor of the latter, as the affinity of oxygen for nitrous acid is less than the affinity of oxygen for copper. Nitric acid is composed of one atom of nitrogen united to five atoms of oxygen. The more complex the compound body is, as a general rule, the more readily is it decomposed, and the fifth atom therefore of oxygen, being retained with a slight affinity, requires but little force to withdraw it from the other four atoms, thus leaving nitrous acid. The increase of power of Grove's battery over the sulphate of copper battery, is equal to the difference of affinity between oxygen for nitrous acid and that element for copper; and its force is equal to the affinity of oxygen for zinc, minus the affinity of oxygen for nitrous acid. The zinc plate, or cylinder, of this acid, is immersed in a solution of sulphuric acid, consisting of one part of the acid to six or eight parts of water. A porous cup of baked earthenware, but not glazed, fits inside of the zinc cylinder. This cup is filled with strong nitric acid. Or it may be filled with equal parts of sulphuric acid and water, into which there is put a tablespoonful of pulverised nitrate of potash, or saltpetre. The platinum strip, or negative plate, is inserted into this fluid. In the latter case, as the nitric acid necessary for the action of the battery is required, it is evolved from the saltpetre, the sulphuric acid taking its place in combination with the potassa.

This battery is the most energetic one known. Twenty square inches of zinc surface of this battery was found, by its magnetising power, to afford a current of greater quantity than a sulphate of copper battery exposing two hundred and ten square inches of zinc. (Davis.) Besides possessing so much greater quantity, this battery has three or four times the intensity of the preceding battery, and six times that of Smee's. This battery is likewise very constant, and hence is used extensively for the purposes of electrotyping.

Bunsen's Battery is similar to Grove's, except that the negative element instead of being platinum, is carbon; but as platinum has become much cheaper, and as there is so small a quantity used in

the Grove's battery, the substitution of carbon for platinum is no great desideratum.

CONDUCTION OF GALVANISM.—Metals exhibit a great disparity in their power of conducting the voltaic fluid. Silver appears to be the best conductor; then follow copper, brass, iron, and finally platinum, which is the poorest conductor among the metals. Copper, on account of its cheapness, is generally used for conductors, although for telegraphic purposes iron is resorted to in consequence of its great cheapness over copper. The greater the length of wire, the greater the resistance to the passage of the fluid, and therefore a long wire conducts more slowly than a short one. If the wire is lengthened, then it must be enlarged, that the resistance to the passage of the fluid shall be less.

When, on the contrary, it is desired to employ poor conductors, the platinum, or iron, is employed. It appears that heat is generated in a ratio to the resistance to the passage of a voltaic current; therefore if a wire be both small and a poor conductor of electricity, the heat evolved by the passage of a large quantity of electricity is great. The wire becomes so strongly heated as to ignite, and finally to melt, or be dissipated in vapor. It is upon this principle that the Submarine-Battery, or Torpedo, is constructed. The wires which conduct the electricity to the submerged gunpowder, or gun-cotton, must be large, that the fluid may pass through them with as little obstruction as possible. At the terminations of these wires, there is a short thin wire of platinum, passing from one termination to the other, and thus completing the circuit. The electricity in passing through this thin wire, in consequence of its small size and great resistance to the passage of the fluid, quickly heats it to ignition, and the explosion of the gunpowder follows. This ignition of a platinum wire has also been used for the purpose of firing a mixture of oxygen and hydrogen gases.

GALVANO-DECOMPOSITION.—In the development of electricity in the galvanic battery, it was stated that as a necessary condition, there shall be a decomposition of the liquid in which the plates are immersed. If the poles of the battery are immersed in any liquid which is capable of electrical decomposition, then there will follow a separation of its elements, the amount of decomposition depending upon the quantity of electricity employed. Some fluids, however, conduct the electricity very well without undergoing decomposition. This is the case with solutions of various metals in mercury, and with fused alloys. Some substances completely stop the passage of the current, and therefore undergo no decomposition. If the electricity, however, possess great intensity, it will then force itself through the liquid by mere mechanical means. But if the liquid allows more or less readily the continued egress of the electricity, then it is decomposed. To this class belong all those substances termed electrolytes. In these decompositions there is

always a certain class of substances which appear at one pole, while another class appear at the other. For instance, when solutions of metallic salts are decomposed, the metal or base always appears at the negative pole, while the acid, or acid radical, appears at the positive pole. In these decompositions, the elements are always liberated close to the poles, and according to their various natures are either evolved as gas, or deposited in the solid form, or dissolve in the undecomposed liquid surrounding the poles, or combine chemically with the conductor, or with other elements of the liquid, thereby giving rise to *secondary products*.

The electrolytes must be regarded as non-conductors, which although they will not allow electricity of low tension to pass through them, will that of high tension. It is only when the latter passes through that we have decomposition. This decomposition is, however, exactly proportional to the quantity of electricity which passes through the compound. It is also ascertained that for a certain amount of electricity a definite proportion of each element is evolved. These proportions correspond to the chemical equivalents, or combining proportions of those elements.

Only those compounds which contain two atoms of elementary matter, or a compound radical, are capable of electrolysis; as, for instance, one atom of hydrogen or metal with one atom of oxygen, chlorine, bromine, iodine, fluorine, cyanogen, &c. While such compounds as boracic acid (B O_2), sulphurous acid (S O_2), sulphuric acid (S O_3), chloride of phosphorus (P Cl_3) and (P Cl_5), chloride of sulphur ($\text{S}_2 \text{ Cl}_2$), chloride of carbon ($\text{C}_2 \text{ Cl}_6$), bichloride of tin (Sn Cl_2), terchloride of arsenic (As Cl_3), &c., are not decomposable, and act as non-conductors. But if the current is passed through a binary compound such as water, the poles terminating in platinum strips, there will be perceived a stream of gas ascending from each pole, the one of which will be oxygen and the other hydrogen, the volume of the former being only the half of that of the latter. If the wire connecting the positive pole be of some easily oxidisable metal, as iron, the oxygen, instead of being given off as gas, will unite with it, and an oxide of iron will be the result.

It appears, therefore, that some of the elements are always evolved at the anode, or positive electrode, while others are evolved at the cathode, or negative electrode. Those which are evolved at the positive pole, or electrode, are termed by Faraday *anions*, and those which make their appearance at the negative pole he calls *cations*. The anions, or electro-negatives, are oxygen, fluorine, chlorine, bromine, iodine, and cyanogen; probably also sulphur, selenium, and sulpho-cyanogen. The acids are also included in this class by Faraday. The cations, or electro-positives, are hydrogen, the alkali-metals, magnesium, manganese, antimony, bismuth, zinc, cadmium, tin, lead, iron, cobalt, nickel, copper, mercury, silver, gold, platinum, and ammonium. The salifiable bases are also classified by Faraday in this list.

There is a difference between direct and indirect decompositions by the electrical current. The direct decomposition arises from the immediate action of the current, but the substance liberated may, when the liquid is a mixture of several compounds, exert a decomposing action upon a compound upon which the current does not act directly. For instance, aqueous ammonia is resolved into hydrogen gas at the negative electrode, and nitrogen gas at the positive electrode. The water alone in this instance is directly decomposed, and the oxygen, which passes to the positive pole, combines with the hydrogen of the ammonia, setting free its nitrogen.

Instruments are constructed termed *Voltascopes* or *Voltameters*, which are intended for ascertaining the amount of electricity generated in a battery. The current is passed through water slightly acidulated, in order to render it a better conductor, and the amount of gases generated is exactly proportional to the electricity which passes. A battery which retains a platinum wire $\frac{1}{64}$ of an inch thick in constant ignition during the whole time occupied by the decomposition, decomposes one grain of water in $3\frac{1}{2}$ minutes. This quantity of electricity is equal to a powerful stroke of lightning. (Faraday.)

An atom, or equivalent, of one electrolyte, requires for its decomposition the same amount of electricity as is required for an atom of any other electrolyte. The strength or the feebleness of the affinity does not alter this law. For instance, if the current is passed through the solutions of several metals, they are precipitated in the ratio of their atomic weight, *id est*, about four times as much silver as copper. The quantity of electricity which one atom of liquid requires to decompose it, is equal to the quantity which an atom of the same liquid evolves during its electro-chemical decomposition by ponderable bodies.

The amount of metal precipitated is in a ratio to the amount of zinc dissolved in developing the current of electricity. If the zinc is corroded rapidly, then the metal is precipitated rapidly, and *vice versa*. If a battery be constructed of lead and platinum plates, and another battery of copper and platinum plates, the weight of the lead plates being to that of the copper plates in the ratio of the atomic weights of the metals, viz., 104 to 32, and the currents of both batteries be passed through solutions of nitrate of silver contained in separate vessels; then, when all the copper and lead are dissolved, the quantities of silver separated in the two vessels will be found to be equal. (Matteucci.)

A solution of iodide of potassium is more easily decomposed than any other salt. Instead of the elements of water appearing at the poles, those of the salt make their appearance there—the iodine at the positive electrode, and potash at the negative one. In this case the metal potassium, having a strong affinity for oxygen, decomposes the water, and combining with its oxygen, makes its

appearance as potash. When iodine combines with starch, the resulting compound, the iodide of starch, is of an intense blue color. The *Thermo-Electric Pile* of Melloni was constructed for the purpose of ascertaining the passage of very weak currents of electricity, which the decomposition of the iodide of potassium and the consequent production of the blue iodide of starch indicated. By this means, that philosopher determined that even insects possess vital heat.

The phenomena of decomposition by electricity may be observed by using a vessel which contains a porous diaphragm passing through the middle of it, by which there is formed a separate apartment for each pole. This diaphragm may be composed of plaster of paris, or of unsized paper. If this apparatus is filled with a solution of sulphate of soda, and this colored blue by the infusion of red cabbage, the passage of the voltaic current through it will be attended with such a change in the color of the fluid as will indicate the decomposition of the sulphate of soda. The acid of the salt will pass through the diaphragm to the apartment containing the positive pole, while the alkali will be drawn to that containing the negative pole. The acid will change the color of the blue fluid to red, while the alkali will change that in the other apartment to green. If a solution of the chloride of ammonium is placed in the cells, to which is added red cabbage infusion to impart a blue color to the solution, the color at the positive pole will soon disappear, in consequence of the liberated chlorine bleaching the color. In the negative cell, ammonia and hydrogen are set free, and hydrochloric acid and oxygen should have been set free in the positive one, if the chloride of ammonium be regarded as a muriate, which, in the present state of science, is inadmissible. The true explanation is, that in the positive cell there is liberated the chlorine, while ammonium appears at the negative cell, but not being able to exist in an isolated state, is separated into its components, ammonia and hydrogen.

During the time that water is undergoing electrolysis, there is developed at the positive pole a peculiar odor. This odor, if the two gases are collected separately, is confined exclusively to the oxygen. This same odor may be detected in the atmosphere which surrounds an electrical machine, when it is in operation, and has given rise to considerable speculation of late among physicists. It is now considered as simply oxygen in an allotropic condition, or perhaps this gas combined with an equivalent quantity of electricity, and therefore might be designated as the *Electride of Oxygen*.

Electro-Metallurgy.—It has been stated that solutions of metallic salts, when subjected to electrolysis, undergo decomposition, the acid being conveyed to the positive pole, while the reduced metal is deposited upon the negative pole. Thus the origin of the art of electro-metallurgy. The great desideratum in the deposition of

metals is to obtain them in that state termed the *reguline*, or in a tough, malleable, coherent state, suitable for the purposes required.

Metals are thrown down by the galvanic current in three conditions: 1, As a black deposit; 2, As a reguline, or malleable metal; and 3, As a crystalline deposit. The water and the metallic salt, both of which exist in the battery, are both liable to decomposition. When the water is decomposed, the hydrogen passes to the negative pole. This hydrogen, if evolved at the same time that the metal is deposited, gives rise to the black deposit. This hydrogen appears to be thrown down with the metal, and thus the black pulverulent substance. If, therefore, the water be too strongly acid, it becomes a better conductor of electricity, and will be more easily decomposed, whereby its hydrogen being released, the black deposit occurs. If the salt is difficult to decompose, acid is often added to increase the conductivity of the solution; but too much must not be added, for the reasons just indicated. The conditions necessary to obtain the metallic deposit of a reguline nature, is by adding sulphuric acid to the solution until the point is just arrived at, where copper being still precipitated, hydrogen is about to appear, and then the metal will be deposited in the soft, malleable state. The crystalline state results from the deposition of the metal in obedience to its own molecular attraction. In the reguline state, this is modified by the chemical agency of the elements of water. In all cases, the battery current should be regulated according to the strength of the solution. The following, from Smee, will give the student all that is necessary, in order to insure success in electrotyping. The tendency to the evolution of hydrogen, and to a black deposit of metal, is increased by any of the following means: By increasing the intensity or quantity of the battery; by increasing the size of the positive pole; by decreasing the size of the negative pole; by approximating the poles; by increasing the heat of the solution; by weakening the solution; by making it acid. The tendency to evolution of hydrogen may be diminished, and that to the crystalline form of the deposits increased, by any of the following means: By diminishing the quantity or intensity of the battery; by increasing the negative pole; by decreasing the positive pole; by separating the poles; by saturating the solution; by making it neutral; by diminishing its heat. It will frequently be found that one or more of these means may be employed in a particular operation, while it will be impossible to make an advantageous application of others.

The impression obtained is precisely that of the mould upon which it is taken. Even the slightest mark is faithfully copied, even to the impression left by touching the mould with the finger, or the slightest tarnish. The precipitation of metals, therefore, has become an art, under the designation of Electro-Metallurgy, and has result-

ed in the production of works of the greatest beauty. Gold, silver, and other noble metals, can be thrown upon metallic surfaces with the greatest readiness and purity, and thus we have a means of protection of the latter metals against the action of the weather.

Impressions of medals, &c., may be easily copied by either taking an impression upon their surface, of plaster, of wax, or of the fusible metal. If of the former two, the mould must be brushed over with dry plumbago, or copper bronze, that it may have sufficient conducting power to convey the current over its whole surface, otherwise the precipitation of the metal will not be regularly deposited upon its surface.

Engravings are copied by the electrotpe process which are in every way equal to the original engraved plate. This is done by taking an impression, or mould, in wax, or in copper itself, and thus precipitating a tolerably thick stratum of copper upon that mould. As this is not the place to enter into practical details of the Electrotpe process, the student is referred to works treating especially upon that subject.

Galvanic Etching may be effected by coating the plate with wax, and then drawing lines which will cut through the wax and reach the copper. This plate must be attached to the positive pole of the battery, when the acid of the solution will etch those portions marked, or deprived of the wax coating. This plate may be printed from in the usual way, as is customary with plates etched by nitric acid.

Glycography is the reverse action to the etching process in the previous paragraph. The lines are drawn as in the process for etching. A coat of black-lead, or plumbago, is then brushed over it. This is then placed in the battery, and a coat of copper is thrown upon it, by which the lines marked into the wax are raised. This plate being similar to a wood-cut, it can be used like those plates in letter-press.

When it is desired to precipitate copper on iron or steel, a solution must be used composed of sulphate of copper dissolved in a solution of cyanide of potassium.

The battery most useful for gilding and silvering should consist of six or eight pairs of Smee's battery, or of the protected sulphate of copper battery, or Daniell's battery. The gold solution should be as pure as possible, for it is a general law that when several metals are in solution, the one which is most easily reduced is thrown down first. If, however, the energy of the current is increased, all the metals will be thrown down. For instance, if the gold is alloyed with silver, the latter metal will be thrown down first, if the current is too feeble to precipitate both metals together. If the gold is alloyed with copper, a feeble current will deposit pure gold; but if the current is increased, an alloy of gold and copper of a darker color will be thrown down.

The salt of silver used for the purpose is the cyanide. It is best prepared by dissolving a silver dollar in nitric acid, and then precipitating the silver from its solution either by hydrochloric acid or solution of common salt. The precipitate is washed, and then dissolved in a solution of cyanide of potassium, only using enough of the cyanide to dissolve the chloride. Water is then added to make two quarts of the solution.

The solution of gold employed for gilding is the cyanide. It is prepared by dissolving a five-dollar gold coin in nitro-hydrochloric acid (composed of one measure of nitric acid with four of hydrochloric acid) and evaporating the salt to dryness. This chloride is then dissolved in just enough cyanide of potassium to take it up, or to make a clear solution, which will require about one ounce. Then add water enough to make two quarts of the solution.

Small objects may be gilded without the aid of the battery, by immersing them in the gold solution, and placing a strip of zinc in contact with them. In that case, the object to be gilded, which must be metallic, as, for instance, the face of a watch, acts as the negative plate, while the strip of zinc is the positive element. The zinc is therefore dissolved by the solution, but the feeble current of electricity which is excited only throws down the gold.

Nobili's Rings.—If one of the poles of the battery consists of a plate of polished metal, and the other of a fine platinum wire, and the latter be approached to the former very closely, there will be formed several concentric colored rings, but the aspect of these rings depends upon the kind of metal used and the nature of the solution. If the positive pole is a silver plate, the following solutions will produce the rings, viz.: phosphoric acid, carbonate of potash, sulphate of soda, chloride of ammonium, chloride of potassium or sodium, tartar emetic, sulphate of zinc, chloride of cobalt, sulphate, nitrate, and acetate of copper, chloride of platinum. On plates of gold or platinum, solutions of sulphate of manganese, nitrate of bismuth, and acetate of lead, form negative rings. If the silver plate forms the negative pole of the battery, it has these rings deposited upon it in solutions of tartar emetic, salts of copper, or chloride of platinum. The rings produced by acetate of lead exhibit, by chemical analysis, the reactions of the peroxide of that metal. Almost any metal exhibits these beautiful prismatic rings, if it is previously heated in the air until it becomes covered with a coating of oxide. The more oxidisable metals, when used as positive poles in solutions of acetate or nitrate of lead, do not allow of the formation of the peroxide of lead, except iron, and that metal only on account of its assuming the passive state. Iron, under these circumstances, soon becomes red, blue, yellow, &c., until the colors finally become so deep that they cannot be distinguished.

To form Nobili's monochromatic deposit on platinum requires one of the following solutions: chloride of manganese in 8 parts of

water; sulphate of manganese and potash in 12 parts of water; acetate of manganese in 15 parts of water; succinate of manganese in 16 parts of water; or hippurate of manganese in 12 parts of water. A well-polished platinum capsule is filled with one of these solutions, and is connected with the positive pole of a battery of four pairs of plates, each 36 square inches surface, immersed in dilute sulphuric acid. If a stronger battery is used, the solutions of the salts must be more dilute. A disk of platinum, three-quarters of an inch in diameter, is then dipped horizontally into the liquid to form the negative plate. With sulphate of manganese and potash, or with succinate or acetate of manganese, one tint is produced; first golden-yellow, then purple, then green. The current must be stopped when the desired tint is obtained. With hippurate of manganese its tint is first golden-yellow, then of a splendid bluish-purple red. Chloride of manganese yields very beautiful broad alternating rings of purple-green, golden-yellow, and blue, surrounded by a broad belt of golden-yellow. (Böttger.) These rings may be formed by a simple galvanic circuit. Immerse a plate of silver in a solution of sulphate of copper, and touch it with a piece of zinc, when there are formed about the point of contact several blue and green rings. When the contact is broken, these rings pass through several changes of color, finally assuming those of dark blue and light green.

THERMO-ELECTRICITY.—If two metals, joined together by solder, or one metal in two different states, be heated, there is a development of electricity, the current flowing from one of the metals, through a conductor, to the other. This species of electricity is termed *Thermo-Electricity*. Two strips of metals, the one German-silver and the other brass, will illustrate thermo-electricity. They must be soldered as in Fig. 28, the strip G being the German-silver, and the other, B, the brass.

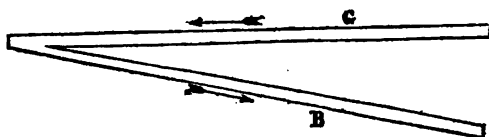


Fig. 28.

When the junction is heated by a spirit-lamp a current is excited, flowing in the direction of the arrows, or from the German-silver to the brass. Although two dissimilar metals, as is the case with the galvanic battery, produce the strongest current, still one metal will answer the purpose if it is bent, the middle portion which is bent being twisted. If the heat is applied to one side of the twisted portion, a current will be developed, flowing from the untwisted part to that which is twisted.

If two platinum wires, of different diameters, are brought in contact and heated, a current flows from the thinnest wire to the thickest one.

The thermo-electrical current is referred to the difference in the conducting powers of substances, and also to their different molecular states, such as that of crystallisation, which is thought to be the result of a peculiar electrical condition of the particles. But where the same metal, in different conditions, is made use of, the development of the current is thought to arise from the different conducting power of the metal on each side of the point of contact, or of the heated place, or by the obstruction of the heat of the twisted portion of the wire. As this department of science has not been investigated with sufficient rigidity, the above explanations may undergo considerable modification. The metals differ greatly in their power of developing a thermo-electrical current, but none of them give such good results when their point of contact is large, than when it is but just slight enough to allow the free passage of the current, and no more. In the case of a large contact, there is sufficient room for the return of the current to the metal from whence it proceeded, without passing through the exterior circuit.

The metal which develops the current is analogous to the zinc element about the battery, while the metal which receives the current may be compared to the copper element. Therefore the positive pole of the thermo-electrical battery proceeds from, or is attached to, the negative plate, or that which receives the current, and the negative pole is attached to the other metal.

In the following thermo-electrical elements, that metal corresponding to the zinc one of the battery will precede, while the succeeding one will answer to the copper plate.

German-Silver and Antimony.—These two metals give a greater current than those which succeed; for, while these metals deflected the galvanometer needle 85° , those of bismuth and antimony deflected it only 75° . When the temperature was brought up to the freezing-point of bismuth, the German-silver and antimony elements gave a deflection of 88° , while the others gave but 82° .

Bismuth and Antimony.—A battery of these elements may be used where the object is to use feeble heat, as the fusibility of bismuth will preclude a strong one.

German-Silver and Carbon.—The carbon used for this battery was that carbon termed Graphite, a hard metal-looking substance, deposited in the interior of gas retorts. German-silver is an alloy of copper 50 parts, zinc 30 parts, and nickel 20 parts.

The following table from Davis's Manual of Magnetism will give the deflections of the needle for different combinations of metal. These deflections admit of comparison with each other to a considerable extent, though not so strictly as if wires of the same size had been employed in all the experiments. It must be remembered,

too, that as the needle approaches the extreme angle of deflection 90° , a much greater increase of the current is required to carry it a few degrees farther towards 90° than when it is nearer the zero. Hence a deflection of 40° does not indicate a current of half the power of one of 80° , but considerably less. Nor can momentary deflections be compared with permanent ones in extending the power of the currents; as a current which, by its first impulse, causes the needle to traverse a large arc, may not be able to maintain more than a few degrees of steady deflection. (Channing.)

CURRENT FLOWS THROUGH HEATED JUNCTION.		DEFLECTION OF THE NEEDLE.	CURRENT FLOWS THROUGH HEATED JUNCTION.		DEFLECTION OF THE NEEDLE.
From Positive.	To Negative.		From Positive.	To Negative.	
German-silver.	Antimony	88°	German-silver.	Carbon	82°
" "	Silver	85°	Silver	Antimony	88°
" "	Brass	85°	Bismuth	Antimony	82°
" "	Iron	85°	"	Silver	78°
" "	Palladium	85°	"	Palladium	85°
" "	Copper	85°	"	Carbon	85°
" "	Cadmium	85°	"	German-silver.	83°
" "	Zinc	84°	Platinum	Carbon	78°
" "	Platinum	81°	Carbon	Antimony	75°

In the experiments made above, the wires were not soldered, but their ends were brought in contact before the application of heat, and kept so till the termination of the experiment.

The *thermo-electric battery* consists of a series of plates of German-silver and brass, with their ends soldered together alternately at a very acute angle, and prevented from coming into contact by the interposition of paper or pasteboard.

Bismuth and antimony may be used, but in this case the heat applied must be comparatively feeble (not over 300° F.), or the bismuth will be fused.

The instrument termed the *Thermo-Multiplier*, by Melloni, is composed of alternate bars of antimony and bismuth. This instrument is extremely susceptible to the influence of heat, even much more so than the air-thermometer, as by its aid Melloni determined the vital heat of insects. In the thermo-electrical battery, a current of electricity is developed by heating the opposite ends of a series of dissimilar metals. The converse of this can also be attained; for, if the voltaic current is passed through these series of metallic bars, the opposite junction will become heated on one side, while there will be a loss of it on the other. The reversal of the direction of the current will likewise reverse the temperature of the ends of the battery.

ELECTRICITY DEVELOPED BY THE VITAL PROCESS.—ANIMAL
ELECTRICITY.

Several fishes, such as the *Torpedo unimaculata*, the *Gymnotus electricus*, or *Electrical Eel*, and the *Electrical Ray*, have the power of generating qualities of electricity in their bodies, and which is possessed also of great tension. In the electric ray the current proceeds from the upper surface of the body to the under. In the gymnotus or electrical eel the current proceeds from the anterior to the posterior portion of the fish. The electricity, when conducted away by wires, disturbs the magnetic needle, and decomposes liquids such as the iodide of potassium. By using a magneto-electric coil the spark is obtained. These electrical organs of fishes consist of numerous cells, arranged in columns, and divided by septa, or small disks, not dissimilar to the plates in a galvanic battery. These septa are liberally supplied with large nerves, to such an extent as to exceed the rest of the nervous system of the creature. This electrical power appears to be wholly under the control of volition, by which the fish can withhold its electrical power, or release it by a mere effort of the will. This has led to the belief in the identity of the nervous and electrical force, or if not their identity, to their great analogy.

If nervous power can be converted into electrical force, it is philosophical to suppose that the electrical can be converted into the nervous. This idea has led to the introduction of electricity in the cure of disease, in the anticipation that those maladies which arise from the decrease of nervous force may be cured by furnishing a supply of it by the aid of the electrical. This appears to be confirmed by the fact that several diseased subjects have furnished instances of the nervous force being converted into the electrical; and although there are instances of its production in abnormal conditions of the system, the electrical fishes supply us with the production of that force as a physiological phenomenon.

MAGNETISM.

If a current of electricity is passed in the vicinity of a magnetic needle, the latter will have a tendency to arrange itself at right angles to the direction of the current. If the current flows from south to north, and the needle be above it, it will be deflected with its north pole towards the east. If the current is reversed, or the needle is brought below the current instead of above it, then the north pole of the needle will be deflected towards the west. If it were not for the influence of the earth's magnetism, the needle would in these instances arrange itself at right angles to the course of the current; but this being the case, the needle is deflected until it rests

in a state of equilibrium between the two forces. All other known forces exerted between two points act in the direction of a line joining these points. But the conducting wire exerts a force which is at right angles to its own course, while the magnetic pole has a tendency to revolve around the current without increasing or decreasing its distance from it. The force, therefore, is considered as exerted in the direction of a tangent to the circle in which the magnetic pole moves.

If the current be supposed to pass downward, the north pole of a magnet, if free to move, would revolve around the magnet in the same direction of the hands of a watch if laid with its face upward. If the current flows upward, the pole revolves in the opposite direction. The south pole revolves in the reverse direction to the north pole. If the current flows horizontally, the plane of the revolution of the pole will be vertical.

A needle may be so arranged as not to be susceptible to the magnetism of the earth, when it becomes very sensible to the passage of a voltaic current in its vicinity. Such a needle is termed an *astatic needle*. It consists of two needles, one above the other, with the north pole of one opposite the south pole of the other. This needle is so arranged that the wire conveying the current is close to one of them, and therefore acts upon it, while the other, being further removed from it, is beyond the influence of the current. When such a needle is acted upon by the combined influence of several wires wound into a coil, the instrument is termed a *Galvanometer*. The wires in this case pass over the needle, and then turning, pass under it in the opposite direction. Both wires, therefore, conspire to move the needle in the same direction; for it must be recollected that the currents, while passing above and below the needle, act really in the same direction in respect to the movements of the needle, if they pass in opposite directions. It was stated that the current, when passing below the wire, deflected the needle in the opposite direction to that when the current was passing above it; and this would be the case in the galvanometer if the current in both wires flowed in the same direction. But it must be recollected that it flows in opposite directions, and therefore the needle is deflected by the influence of both top and bottom currents.

The galvanometer, or galvanoscope, measures only the *quantity* of electricity, and not its intensity. Machine electricity does not affect the galvanometer, or but slightly, while the current from a small battery, or even one pair of plates, exerts considerable effect upon it. If, therefore, the intense current from one hundred pairs of plates be sent through it, there is but little more deflection than if the current of a single pair of plates is used. The galvanometer therefore takes cognisance of the *quantity* of electricity, or of that which manifests itself in the decomposition of compounds, or the production of magnetic effects.

It was stated that if the pole of the magnet was left free to move in the vicinity of a wire conveying a current of electricity, that it would revolve around the wire. This action is reciprocal, for the wire has as great a tendency to revolve around the magnet as it has to revolve around the wire. If both are free to move they revolve around each other, or in the same direction around a common centre of motion. If the magnet itself is the conductor of the current, it will revolve about its own axis. Apparatus has been constructed by Palmer and Hall, of Boston, and by other philosophical instrument makers, to illustrate this, where the current being passed through a magnet fixed perpendicularly, and which being free to move, revolves rapidly around its own axis. In this case the current must be transmitted through the magnet, only to its middle, where it is carried off, so that only one pole revolves around the current. If the current were carried entirely through the magnet, the south pole would have a tendency to revolve in one direction, while the north pole would strive to revolve in the other, and the two forces would equilibrate each other, and there would be no motion at all.

The Gold-leaf Galvanoscope.—This instrument does not indicate the quantity of electricity, but is a very delicate indicator of its presence. It is composed of a strip of gold-leaf which passes down between the two legs of a permanent magnet. When a feeble current of electricity is transmitted through the gold-leaf, it is bent either towards one leg of the magnet or the other, depending upon the direction of the current, in either case having a tendency to move away from the poles of the magnet, or to revolve about them, the action of the current equally on both poles conspiring to force the gold-leaf in a lateral direction from between the poles. The direction of the current, and the presence of the feeblest currents, are indicated by this instrument.

While transmitting a current of electricity, a coil of wire manifests all the reactions of a magnet. While one face of the coil exhibits north polarity, the other shows south polarity. The poles are reversed upon reversing the direction of the current. By placing a coil of wire between the poles of a permanent magnet, so that it is free to move, the coil rapidly rotates while the current is passing through it. This can only be attained by reversing the direction of the current twice during each revolution, by means of a pole-changer fixed on the axis of motion. As by this means the direction of the current is twice changed during one revolution of the coil, the polarity of the coil is twice changed, and thus the motion. A coil of a rectangular form will revolve with more rapidity than one of a circular form, from the fact that this form presents the face of the coil in closer proximity to the magnet, and likewise the entire length of its legs.

ELECTRICITY IN REFERENCE TO THE EARTH.

If a piece of steel which has been rendered magnetic be suspended so as freely to move, it will arrange itself with one of its ends or poles pointing nearly north, while the other will assume a southern direction, or nearly in a plane passing through the geographical poles of the earth. It is probable that the magnet or the mariner's compass was known to the Chinese several centuries before it became known in Europe. It was not until the eleventh or twelfth century that this important instrument became known to Europeans, while Klaproth informs us that the Chinese used the compass in the second century, and that it was communicated to Europe from China through the Arabs.

If a piece of steel be rendered magnetic, and then suspended in such a way as to possess perfect freedom of motion, it will assume a determinate direction, which will correspond nearly with the geographical poles of the earth. But if this needle be so balanced as to stand perfectly horizontal before it is magnetised, after magnetisation one end of it will be found to have become heavier than the other, or to *dip*. In this hemisphere the north pole of the needle will dip, while in the southern hemisphere the south end will dip. This dip decreases as we approach the equator, and increases as we draw nearer to the magnetic poles, until when there, the needle assumes a perpendicular position. At the equator it stands horizontal.

It was supposed for a long time that the magnetism of the earth was caused by a vein or stratum of magnetic oxide of iron, which extended in the direction of the poles of the earth, and by its attraction gave the directive tendency to the needle. Or, in other words, that an enormous magnet extended the length of the magnetic meridian, its poles being near the geographic ones of the earth. But since the discovery of the influence which a current of electricity exerts upon a magnet, causing it to assume a position at right angles to the direction of the current, another belief of the earth's magnetism gained credence with philosophers. It is supposed that currents of electricity are continually passing around the earth, near to its surface, and at right angles to the direction which the needle assumes, and that it is by virtue of these currents that the needle is forced into the position of north or south, or in a direction at right angles to the course of the current. These earth-currents are supposed to be thermo-electric, and originate from the unequal heating of the earth by the solar rays.

It will be recollected that it is the south magnetic pole which is nearest to the north geographical pole, and *vice versa*; for it is the south magnetic pole which attracts the north pole of the magnet, while the north pole attracts the south pole of the magnet.

The *Aurora Borealis* affects the magnetic needle considerably, causing it to vibrate. This ensues especially if the auroral beams are near the zenith, while if they are near the horizon the needle is but little affected. These auroral beams are therefore supposed to be currents of electricity flowing from the poles of the earth towards the equator. But the recent view of Sir John Ross is gaining credence, that the *Aurora Borealis* is occasioned by the action of the sun, when below the pole, on the surrounding masses of colored ice, by its rays being reflected from the points of incidence to clouds above the pole which were before invisible. If these views be true, how is it that the auroral beams affect the needle so strongly, especially when they approach the zenith?

INDUCTION OF MAGNETISM BY THE INFLUENCE OF A MAGNET.

When a rod of iron, or nickel, or cobalt, is brought in contact with the pole of a magnet, the rod itself becomes magnetic by induction. If it be brought in contact, or in close vicinity of the north pole of the magnet, that end of the rod will be a south pole. That is, the north pole of the magnet induces south polarity in the end of the rod nearest to it, and north polarity in the opposite end. If another similar rod be brought in contact with the lower end of the rod No. 1, the rod No. 2 will have magnetism induced in it from No. 1, the north end inducing south polarity in the nearest end of No. 2. Several rods may thus have magnetism induced in them, each rod becoming more feebly magnetic. If the rod be one of soft or annealed iron, the magnetism only remains so long as the rod is in contact, or is in the immediate vicinity of the magnet. But if the rod be steel, the magnetism remains permanent. If the north pole of a bar-magnet be placed in contact with the middle of a bar of iron, then the place immediately beneath the pole will acquire south polarity, while the two ends of the bar will become north poles. If the north pole of the bar-magnet be brought in contact with the centre of a circular piece of iron, its rim or circumference will have north polarity, while the centre will manifest south polarity. If it be in the form of a star or spur, the points of the star will have north polarity developed in them, while the centre will be a south pole.

If the pole of the magnet be dipped in a number of small nails or tacks, they will adhere to it, each tack becoming a magnet by induction—some from the inductive action of the magnet directly upon them, and others from the secondary inductive action of those tacks upon others in contact with them.

If the bar or armature be in the form of a Y, and the upper terminations of the bar be applied to the two poles of a U magnet, the lower portion of the bar will exhibit no magnetism. The reason of this is obvious; for while the north pole of the magnet induces

north polarity in that extremity of the armature, the south pole induces south polarity into it, and thus the two opposite polarities neutralize each other. It is for this reason that a thin piece of iron, if placed in contact with the end of the pole, will not adhere, for while the side of the iron which is nearest the pole acquires opposite polarity, the other side acquires a like polarity. The two poles being so near, neutralise each other, and the piece of iron slides to the side of the pole. Here it adheres, for the ends of the plate then become poles instead of the sides, and being farther separated than the sides, they do not neutralise each other, and consequently the plate adheres to the pole of the magnet.

The inductive action of a magnet is not destroyed or deteriorated by the interposition of any body which is not itself susceptible of magnetism. If a piece of glass be placed between the magnet and a piece of iron, the induction is just as strong as it would be were there nothing interposed.

Although there are some analogies existing between magnetism and common electricity, still there are many instances where it fails. If a long cylinder have its two electricities separated by induction, the positive being accumulated in one end and the negative in the other, the cylinder may be separated in the middle, and the two electricities may thus be obtained separate. But this is not the case with a magnet, for if it be fractured in the middle, we will not obtain south polarity on one side and north polarity on the other, but each half of the magnet will be a complete magnet with poles on each end. These halves may be again broken, and each fragment will be a perfect magnet, with its south and north pole as strongly developed as those of the original magnet. Thus, instead of a loss of the magnetic force there appears to be a gain. This is further illustrated in the "touching" of magnets, where the steel after being forged in the proper shape for magnets, and being polished, is brought in contact a number of times with a strong permanent magnet, and is thus charged. Any number of these magnets may be charged thus, while the original magnet really gains power by the operation.

It is for this reason that *armatures* or *keepers* are kept in contact with permanent magnets, for by their continual reaction upon the poles of the magnet, its magnetism, instead of undergoing a diminution of force, is thereby increased.

INDUCTION BY THE INFLUENCE OF A CURRENT OF ELECTRICITY.

If the current of electricity flows along a wire from the left hand towards the right, and a short iron rod be placed vertically in front of the wire, and close to it, the rod becomes a magnet, with its north pole below the wire. If the rod is transferred to the farther side of the wire, then the poles are reversed. If the rod is held horizontally

above the wire, its north pole is nearest to the observer; and if held below the wire, its south pole is nearest. If the rod is of soft iron, the magnetism disappears as soon as the current is broken, or the rod is removed beyond its influence.

In order that the student may have a right comprehension of the polarity of the magnet when acquired by induction from a current, the following may be easily remembered. If the current is flowing along the wire downward, with a bar held before us at right angles to the direction of the current, the end towards the right hand will be the north pole, and the left-hand end the south pole. If the direction of the current is reversed, that is, flows upward, then the polarity of the bar is reversed likewise.

This current of electricity is possessed of attractive and repulsive forces. If, while the current is passing along the wire, a needle suspended by a fine thread is brought close to it, the needle is attracted by the wire. This can be more strikingly illustrated by the magnetic needle, for if it is brought close to the wire, with its poles the reverse of the iron rod referred to above, the current will repel it.

The following figures from Davis's Manual of Magnetism illustrates the action of the forces producing attraction and repulsion.

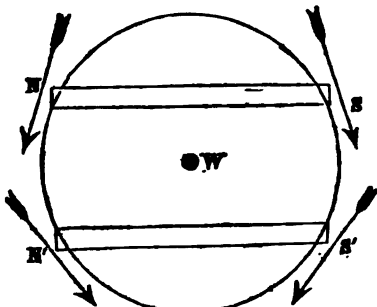


Fig. 29.

W represents the horizontal section of the conducting wire, in which the current is ascending, and N S a magnetic needle, whose poles are at equal distances from the wire. From W, as a centre, a circle is drawn, passing through the poles. The forces which move the magnets are tangents to this circle, and their directions are indicated by the arrows. It will be seen that the resultant of the forces, acting on each pole, urges the centre of the magnet towards the wire. If the magnet be transferred to the position N' S' on the other side of the wire, its centre is urged away from it. The force increases in proportion as the magnet is nearer the wire. When

the poles are at different distances from the wire, the resultant of the tangential forces moves the magnet obliquely towards the wire, until its centre comes in contact with it. If there are two currents moving in opposite directions, one on each side of the magnetised bar, and at equal distances from it, their combined action urges the bar forward, until its centre comes into the same line with the wires. In Fig. 30, let W be a horizontal section of a wire in which the current is ascending, and W' one in which it is descending.

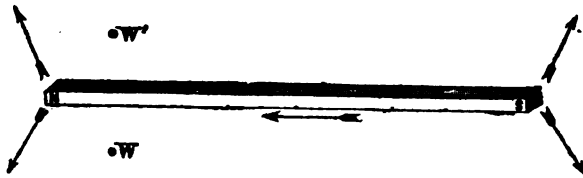


Fig. 30.

The four small arrows indicate the tangents to the circle, drawn as in Fig. 29, from W and W' as centres. At the south pole of the bar, the direction of the forces is nearly opposite, and they neutralise each other in a great degree; at the north pole they approach to parallelism, and that pole is urged forward by a force nearly equal to the sum of the two. As this force is only opposed by the feeble one at the south pole, the bar moves in the direction indicated by the arrow below. When the magnet is not equidistant from the wires, it no longer moves in the direction of its length, as in the out, but its centre is drawn towards the nearest wire with a force which is accelerated as it approaches. (Davis.)

It is not believed that iron attracts the magnet, or that the copper wire through which the electric current is passing possesses these properties through any inherent qualities which may belong to those metals, but it is the current itself which possesses this force. If iron-filings are held against the copper wire while the current is passing through it, the filings will adhere to the wire in consequence of the induction of magnetism into them, by which each particle of iron becomes a distinct magnet. The inductive action of the current is greatly increased by coiling the wire in the form of a helix. In this case each turn adds to the power of the magnetism, until the turns have reached a certain limit, when it ceases. This wire, forming the spiral or helix, must be insulated by being covered with cotton, otherwise the wires will touch each other, by which the current would be prevented from traversing the length of the wire, but would take the more direct route across them.

If a bar of soft iron is placed within this coil while the current is traversing the wire, it instantly becomes a strong magnet, the nature of the poles depending upon which direction the current is sent. If one end of the helix is supposed to be fronting the ob-

server, then if the current be sent through it from the observer, in the direction in which the hands of a watch move when the face is fronting us, then the end of the bar nearest to us will be the south pole, and the farthest end the north pole. If the direction of the current is reversed, then the poles are reversed.

This magnet is termed an *electro-magnet*, and only retains its magnetism so long as the current is passing around it. If the bar should be steel instead of soft iron, then, upon breaking the battery current, the bar will not lose all of its magnetism, but retaining some, will be converted into a *permanent magnet*. The best electro-magnets are those which are made of the purest iron, and the most thoroughly annealed. The softer and purer the iron the stronger is the magnetism, and the more readily is it lost and gained by cutting off or closing the current.

If the helix consists of a wire of considerable length and thickness, and the current passed through it be one of considerable power, then if held perpendicularly, a bar of iron of some weight may be dropped into it without its falling through. It in fact remains there suspended in the air, without touching the sides of the helix. If the helix be of sufficient length and thickness, and the current of corresponding power, several pounds weight may be attached to the bottom of this bar without pulling it through. But if the current flowing through the helix is cut off, the bar instantly falls. If, while the current is flowing through the helix, a small steel bar be allowed to fall through it, the bar acquires magnetism as it passes through, this magnetism remaining permanent.

If a magnetic needle is suspended by a thread near the north pole of this helix, it will pass into it with its south pole. If the current is then reversed, the needle will be repelled, and turning around will again enter the coil, but with the north pole foremost. If, however, the coil should possess sufficient power to reverse the poles of the steel magnet, then the effects just noticed will not take place.

This strong inductive action of a coil or helix has been taken advantage of in the construction of some elegant apparatus illustrative of it. With large magnets and with heavy copper wire, or better still, copper strips, electro-magnets of great power can be constructed, lifting several thousand pounds. If a loose coil of wire is slipped over two electro-magnets and the poles of the magnets be brought in contact, they will adhere with great force, although the coil need not fit the magnets close for that purpose. These are termed the *Helical Rings*, and illustrate the great magnetic force which is derived from the voltaic current when circulating around soft iron.

An electro-magnet with three poles can be formed by the proper construction. An iron bar is wound with insulated copper wire in one direction until the middle of the bar is reached, when the wire is carried around in the other direction until the bar is inclosed. In

that case while the two ends of the bar would be similar poles, the middle of the bar would be the opposite pole. If, for instance, the wire were carried around the bar in the direction of the hands of a watch when its face is fronting the observer, then the nearest pole and the farthestmost one would be south poles, while the middle of the bar would be a north pole. If the direction of the current is reversed, all of the poles will be reversed.

An instrument has been constructed termed the *Magnetometer*, being, as its name designates, an instrument for the measuring of the magnetising power of voltaic currents. It consists essentially of an electro-magnet of the U form, with an armature above it, which is attached to the short arm of a balance-lever. The large arm of the lever is graduated decimally to measure, by means of weights of from 100 grains to 10,000 grains, the force required to detach the armature from the electro-magnet when connected with the battery, the power of which is to be determined. The lever is supported on an axis with knife-edge bearings. A difference of magnetising power of 10 grains can be estimated in a series extending from 100 grains to more than 100,000 grains, or the limit of saturation of the magnet. Another form of magnetometer has been constructed which works by the axial force. The axial attraction of a double helix is used in this instrument, but the principle is the same, the lever being pulled down in a ratio to the magnetising force of the voltaic battery made use of in the experiment.

It will be recollected from our previous remarks and illustrations, that when a current of electricity is passed through a coil of wire, that an iron bar brought with its end to the mouth of the coil is drawn into its hollow with considerable force. This has been termed the *axial force*. Upon this principle there are constructed several engines, as the advantage gained over those constructed with electro-magnets is considerable, the principal one being the avoidance of the secondary induced currents, which, flowing in opposition to that from the battery current, of course weakens it, often almost to entire neutralisation.

These axial engines are all constructed upon the same principle. An armature is forcibly drawn into the coils when the battery current is closed. Two coils, and often four, are placed side and side. The armature is formed not unlike a U magnet, the legs of which are drawn into the coils when the current is closed. This motion is converted into rotary motion by the usual mechanical contrivance.

The *Electro-Magnetic Telegraph* is perhaps the most important application of electro-magnetism that has been made. The telegraph of Wheatstone, of England, works by the deflection of a needle. This telegraph is not so efficient as that of Morse, which is used exclusively in this country. The telegraph depends for its success altogether upon the attraction of the electro-magnet for its arm-

ature. It consists therefore of the electro-magnet, its armature, and a lever. At the extremity of the lever there is a point which presses upon a strip of paper, whenever the magnet draws down the keeper or armature. By this means we can produce a series of lines and dots, the length of the former, or of the spaces between them, being regulated by the length of time the battery current is closed by the operator. The paper passes slowly under this steel point, being drawn through by clock-work, while the operator, by means of the signal key, closes the current in accordance with the length of the lines he may wish to produce, or cuts the current off agreeably to the length of spaces he wishes introduced between the words. These short and long lines, or dots and spaces, have their value as regards the alphabet, and thus words are transmitted with great rapidity by the practised operator.

It was customary when the telegraph was first introduced to use two wires, one for conveying the current to the place whither the words were to be sent, and the other for its return. But the earth itself is now used for the latter purpose, it having been found that it is a sufficient conductor to convey the current back to the battery. For this purpose the poles of the battery and register are connected with large metallic plates, which are sunk in the ground at each terminus of the wires.

It formerly required a number of pairs or batteries to work the telegraph even for a comparatively short distance, but this has been obviated by the invention of the Receiving Magnet. This is an electro-magnet of great delicacy, which is placed at the termination of the wire. This magnet moves an armature only sufficient to make a contact between a platinum point and surface, which are placed in the circuit of another small battery immediately on the spot. This battery does all the work, as its current is only necessitated to traverse a short length of wire in its passage to the registering electro-magnet.

The axial force has been made available for the purpose of telegraphing. In this case the marks are made upon the paper by the force which draws a piece of iron within a coil, as has been noticed before. This force was first suggested and the first engine constructed for its use, we believe, by Daniel Davis, of Boston, but although more sensitive than the telegraph of Morse, has not yet been put into use.

The deflection of the gold-leaf galvanoscope has been suggested as a means of telegraphing. Its extreme delicacy to a current of electricity would be a strong recommendation to its use, but there would be no means of registering its deflections, while its susceptibility to atmospheric electrical influences would probably preclude its use.

The transmission of the electrical current through a wire is almost instantaneous. According to the latest experiments its veloci-

ty is equal to that of light through the planetary space, or equal to 200,000 miles in a second of time. (Gmelin.)

INDUCTION OF ELECTRICITY.

Induction by the influence of a Current of Electricity.—Attraction and repulsion are exerted by electricity both when at rest and when in motion. A body which is electrified by the machine-electricity will attract and repel light bodies which are brought in its vicinity; having previously induced electricity similar to its own or that of an opposite nature into them. If the substance is repelled, the electrified body communicates a portion of its own electricity to it; but if it is attracted, it induces the opposite electricity to its own in the end nearest to it. But a wire through which a current is transmitted does not exert such influences upon light bodies. If two currents are flowing in the same direction they attract each other, and when passing in opposite directions they repel each other. In common electricity two bodies charged with positive electricity, or with negative electricity, repel each other; but if one of the bodies is charged with positive, and the other with negative electricity, they attract each other.

The attractions and repulsions of wires conveying voltaic currents are termed magnetic attractions, as this species of attraction is not dissimilar to the attractions of two magnets when they are presented end to end. That this attraction is really magnetic, may be illustrated by suspending two short iron wires over the wire which is transmitting the voltaic current, when they will become magnetic, with the attractive and repulsive powers characteristic of the magnet strongly developed. The current, with the peculiar attractive and repulsive powers it manifests, depending upon the direction one current takes in reference to another, should be regarded as the primary action, as it is undoubtedly the cause of the attractions and repulsions of magnets. The true explanation of magnetic attractions and repulsions may be referred to those of electrical currents, the one or the other transpiring as these currents flow in the same direction, or in opposition to each other.

But it is not necessary that the current should be transmitted through wires in order that these attractions and repulsions shall manifest themselves. Two streams of common electricity passed through a vacuum attract and repel each other, or this will happen through the air with equal facility.

The attractions of a current may be witnessed by simply coiling a wire into the form of a loose helix, and supporting it in a vertical position, with the lower end dipping into mercury. Upon passing the current through it, the wire will spring up and down with great rapidity. This is caused by the attractions of the different portions of the current for itself as it passes around the spiral path, and this

attraction lifts the wire out of the mercury. This cuts off the current, when by its elasticity the wire is forced into the mercury; but then closing the current again its attractive influence is exerted, and again the wire is lifted out of the mercury. If a bar-magnet is held into the helix, the movement becomes still more rapid. An iron bar introduced into the helix becomes a magnet, but only transient if soft iron, but permanent if of steel.

The *Electro-Dynamic Revolving Coils* are an illustration of the attractions and repulsions of currents. They consist of a circular coil of wire which rotates on a vertical axis within a larger coil. The inner coil has its current reversed twice in each revolution, which is effected by means of a pole-changer fixed on its axis of motion. The attractions of the currents in these coils are the cause of their revolution.

The Electro-Dynamic theory of Ampère has been generally adopted in the explanation of the phenomena of magnetic attraction or repulsion. It ascribes the action of currents upon each other, or of magnets upon each other, or of these exerted between currents and magnets, to the mutual attractions and repulsions of electrical currents. These currents are thought to be circulating continually in steel magnets, passing around the magnet at right angles to their axis. Thus the steel magnet is similar to the electro-magnet, and owes its magnetism to currents flowing around its circumference, as is the case we know with the electro-magnet. It is supposed that in steel each particle of the metal has currents flowing around it continually, and that by the process of charging, these currents, which previously flowed in every direction, are diverted into a uniform direction, by which magnetic power is developed. In fact, the magnetism of the earth itself is due to electrical currents flowing from east to west, and which currents are supposed to be thermo-electric, caused by the unequal heating of the earth's surface by the sun's rays.

It was stated that the action of the force which the electric current exerts is in the direction of a tangent to a circle drawn around the wire conveying the current. The theory of Ampère removes this anomalous action. The action of a current upon a magnet may thus be stated: when the magnet is brought near to the wire which is conveying the current, and the magnet is parallel to the direction of the current, then the current is flowing at a right angle to those supposed to be flowing around the magnet. The needle immediately arranges itself at right angles to the direction of the current, so that the currents flowing around its axis, and that flowing through the wire, shall be parallel. The attractions and repulsions of two permanent magnets may be accounted for upon the supposition of electrical currents flowing around their axes at all times. When similar poles are brought in each other's vicinity, then the currents are presented to each other as flowing in opposition; but

when the north pole of one magnet is brought to the south pole of another, then the currents flowing in parallelism attract each other. This may be rendered plain by substituting helices instead of magnets, when the curvature of the wire will indicate the direction of the flow of the current, and it will be found that the helices act upon each other as would two magnets similarly suspended. The revolution of a conducting wire around a magnet, or of a magnet around a wire, depends upon the same principle as the rotation of one current under the influence of another.

THE INDUCTION OF A CURRENT ON ITSELF.

If the poles of a single cup of Smee's battery are connected by a short copper wire, and the wire be disconnected with the battery, there will be no spark discernible at this breaking of the contact. But if the wire connecting the poles be fifty or a hundred feet in length, then upon breaking its connection with the battery, a bright spark will be perceived. If this wire is coiled into a helix, the spark will be still more vivid. The length of wire necessary to attain the maximum effect, depends upon the intensity and quantity of the battery, and upon the size of the wire. With the sulphate of copper battery, or with several pairs of Smee's battery, a wire of 50 feet (No. 16) would probably be the proper length. If the wire is of a greater length than this, it should be of a greater diameter; and if a battery which possesses both greater quantity and intensity be used, then the length of the wire may be still further increased.

When the wire is two or three hundred feet in length, a shock will be felt at the breaking of the circuit; but if the wire is shorter, then the shocks can only be felt through the tongue. At the length of 500 or 600 feet the maximum of effect is obtained, and therefore the addition of more wire only retards the effect. If the battery possesses greater quantity and intensity, the length of the wire may be increased before the maximum of effect is obtained. If a thin narrow sheet of copper, or a ribbon, is made use of, the brilliancy of the spark is increased, while the shock is quite perceptible. In this case the body must not be interposed in the direct circuit with the coil, as in that case the battery current will probably possess too low an intensity to pass through the body. For the purpose of breaking the current with rapidity, a little instrument is used, called an *Electrotome*, which is often made to go by clock-work; but the battery current itself is used more generally for that purpose, the circuit being broken by the alternate attractions of an electro-magnet for an armature, as will be described hereafter.

The sparks and shocks which a long wire, or ribbon coil, gives, are due to secondary currents that are induced in the wire at the instant of opening or closing the circuit. The current which is derived from the battery is termed the primary current, while the

one of still higher intensity is designated the induced secondary. It is the latter alone which is felt as shocks upon breaking the circuit as mentioned above.

The primary and the secondary currents may be separated from each other by the following arrangement: Pass the battery current through the spiral of copper ribbon mentioned above. Then attach wires, with handles to them, to a similar spiral, and hold this second one above the primary one, while the hands grasp the handles. If now the wire of one of the battery poles is drawn across a rough file or rasp, so that the current shall be broken rapidly, a succession of shocks will be felt proceeding from the upper coil. As the wire in passing over the rasp disconnects the battery current, a secondary induced current is developed in the secondary coil. This is felt as a strong shock, as it passed like a momentary wave through the body. In order that these shocks shall be distinctly felt, the coil must be a long one, and the battery one of considerable intensity. If a short coil is used, and the battery be a feeble one, then the galvanometer will have to be resorted to for the purpose of testing the passage of the currents or waves. Upon opening the circuit the needle will be deflected considerably, but will immediately return to its former position, indicating the developement of a wave of electricity which was awakened in the upper coil simultaneously with the breaking of the battery current. While the battery current is flowing steadily there is no disturbance of the needle, therefore the developement of the secondary current is only at the moment of opening or closing the battery or primary current. If the current of the upper spiral be passed through a helix, a needle placed within it will be magnetised, but the kind of polarity depends upon whether the current is developed by the breaking of the circuit of the battery current, or by its connection or renewal. Therefore the current developed by the renewal of the battery current flows in one direction, while the current which owes its existence to the breaking of the battery circuit flows in the other direction, so that as the polarity of the needle depends upon the direction of the current, its poles will be governed by whether the primary current is detached or renewed, or whether it owes its magnetism to the *initial* or the *terminal* secondary current. The initial secondary current flows in the opposite direction to the battery current, while the terminal flows in the same direction. They do not proceed from the battery, but doubtless owe their existence to a disturbance of the electricity existing naturally in the wire.

The initial and the terminal sparks can be obtained separately, by dipping the battery wire into a cup of mercury, instead of passing it over the rasp as described. When the wire is dipped into the mercury, a shock is felt. There is likewise seen a bright spark which manifests itself with a pretty sharp snap. When the wire is lifted out of the mercury, another shock is felt, and another spark is

seen. But it will be noticed that the initial produces the brightest spark and the strongest shock. The initial current, therefore, is the strongest one, and as it flows in opposition to the battery current, it greatly interferes with the construction of strong magnets for the purpose of power. It is found that these initial secondaries so interfere with the battery current, that when strong electro-magnets are used for the purpose of power, they almost entirely neutralise the battery current, and that this interference increases with the magnitude of the magnets. The intensity of the terminal is but little increased by the addition of battery power, but this is not the case with the initial, which increases with the addition of the primary current; and for this reason the addition of battery power requisite to work powerful electro-magnetic engines, adds to the intensity of the initial secondary, and this flowing in opposition to the battery current, neutralises it. In quantity the two currents are equal, but the wire coil gives less quantity than the ribbon coil, or a wire coil consisting of larger wire. Thus the same battery, even if its current be one of quantity alone, is capable of inducing either a quantity or an intensity current in wires, depending upon the length and size of the wire. If the wire is not too long and is sufficiently thick, a quantity current is induced; but if the wire is of great length and is very thin, then an intensity current is developed.

If the hands be dipped in the fluids of the last two cups of a series of Smee's battery, whenever one hand is taken out of the fluid, or dipped into it, there is felt a pretty severe shock. These shocks depend upon secondary ones, which are induced in the battery itself, for the primary current of the battery passes through the body without being felt, the secondary battery current only being possessed of sufficient intensity to produce shocks or sparks, unless the battery be one of considerable power.

The interposition of a good conductor of electricity between the primary and secondary coils almost entirely neutralises the intensity. But a piece of wood or glass interposed, exerts no effect, while if a piece of brass or zinc be placed between the coils, the shocks will be scarcely perceptible. The quantity, however, is but little affected, unless the interposed current be of iron, when it is diminished. If the metallic piece has a slit cut out to the centre in the direction of a radius, then the intensity is not at all affected, as the brilliancy of the spark will indicate. It is not necessary, in order to obtain secondary currents, that the primary current should be interrupted, for by altering the distance of the latter current, there are induced secondary ones in the coil. If the current be passed through the first coil heretofore mentioned, and the second coil be moved to and from it, the needle of the galvanometer will indicate the development of a secondary current in the upper coil. This disturbance of the natural electricity of the coil can be illustrated by connecting the battery with the lower coil as before, and holding the upper

coil near to it. If, however, the plates of the battery be now raised and lowered in the fluid, the needle will indicate currents in the secondary coil. Thus a slight alteration of the quantity of the battery current induces secondary currents in a wire placed in its vicinity. These currents produce a more prolonged effect upon the needle than those produced by breaking the current, as they last as long as the movement is continued, while the more rapid movement of the plates or coil induces a secondary of corresponding power.

The reason why the conductor interposed between the two coils neutralises the intensity of the secondary, is referable to a secondary current which is induced in the metallic plate itself. This current then induces a *tertiary* current in the upper coil, and which flowing in opposition to the secondary one induced by the battery current, neutralises it. But when the interposed metal is divided by the slit which penetrates to its centre, then no secondary current is induced, and the tertiary noticed above has no existence. The same phenomena are produced by the introduction of a metal tube into the centre of a wire helix, but if the tube be sawed along its whole length, then the secondary induced into it will cease.

The tertiary current can be separated from the secondary, by the employment of another coil, which must be held close over the secondary one, when its current will induce a tertiary one in the last coil.

The *initial* and *terminal* *tertiaries* both flow in the opposite directions to the corresponding secondaries, for each secondary current must produce two *tertiaries*, one when it begins to flow and the other at its termination.

INDUCTION BY THE INFLUENCE OF A MAGNET.

The department of the science which we shall now devote our attention to, is termed *Magneto-electricity*, because of the development of electricity through the influence of magnetism. If the current which is flowing through a coil surrounding an electro-magnet be interrupted, there is a current induced in the wire. Or if there is a magnet brought near to the electro-magnet, there is induced in the wire surrounding it a current of electricity. That is, when an iron bar becomes magnetised, or demagnetised, there is induced in the wire which surrounds it a secondary current, the direction of the current depending upon whether the magnet approaches or recedes from the iron bar. If a second coil of wire surrounds the primary coil, there is induced in it an intensity current which gives strong shocks. This current is caused by the alternate magnetisation and demagnetisation of the inclosed iron bar; but there is likewise another current excited, which is the result of electro-dynamic induction, and which is so associated with it that the two cannot be separated.

If a coil of wire be passed over one of the legs of a U magnet and removed, the galvanometer attached to the terminations of the wires will indicate currents of electricity that are developed in the wire as the poles either pass into or out of the coil, the direction of the current being reversed as the wire passes up and down. These currents of electricity flow only while the coil is being passed over the leg of the magnet, and cease as soon as the movement ceases. By reversing the pole, the direction of the current is reversed. If a bar of soft iron is placed within the helix, and the pole of a magnet is brought in contact with one of its ends, the sudden magnetisation of the bar induces a current in the wire, but this current only manifests itself for a moment. When the contact is broken, another current of electricity is excited, but its duration is as transient as the other. These currents, therefore, are not due to the magnetic condition of the iron bar, but only to that disturbance incident to its sudden acquisition of magnetism, or to its loss of it.

We therefore perceive that when a piece of soft iron is brought into contact, or in close proximity to a magnet, it becomes a magnet by induction, and that the sudden gaining of this magnetism, or the loss of it, induces in a coil of wire surrounding it, currents of electricity which flows in opposite directions, and which, although transient, are possessed of great intensity. The best contrivance for the production of these effects is to cause a bar of soft iron, inclosed in a coil of wire, to revolve with its ends coming in close proximity to a strong permanent magnet. Such contrivances are termed *Magneto-Electric Machines*, and are extensively employed for medicinal and other purposes. The most perfect instruments of this kind made in this country are those manufactured by *Palmer and Hall*, of Boston, successors to Daniel Davis. It is thus described: In these machines an armature bent at right angles is caused to revolve rapidly in front of the poles of a strong compound U magnet. The magnet is fixed in a horizontal position, with its poles as near the ends of the armature as will allow the latter to rotate without coming in contact with them. The armature is mounted on an axis, extending from a pillar to a small pillar between the poles of the magnet. Each of its legs is inclosed in a helix of fine insulated wire. The upper part of the pillar slides over the lower part, and can be fastened in any position by a bending screw. In this way the band connecting the two wheels may be tightened at pleasure, by increasing the distance between them. This arrangement also renders the instrument more portable than would otherwise be the case. By means of a multiplying-wheel, which is connected by a band with a small wheel on the axis, the armature is made to revolve rapidly, so that the magnetism induced in it by the steel magnet is alternately destroyed and renewed in a reverse direction to the previous one. When the legs of the armature are approaching the magnet, the one opposite the north pole

acquires south polarity, and the other north polarity. The magnetic power is the greatest while the armature is passing in front of the poles. It gradually diminishes as the armature leaves this position, and nearly disappears when it stands at right angles with the magnet. As each leg of the armature approaches the other pole of the U magnet, by the continuance of the motion, magnetism is again induced in it, but in the reverse direction to the previous one. These changes in the magnetic state of the armature excite electric currents in the surrounding helices, powerful in proportion to the rapidity with which the magnetic changes are produced. The helices are so connected as to form a continuous coil. The ends of this coil are soldered to the segments of a pole-changer secured on the axis. Two silver springs press upon these segments, and convey the electricity to the two screw-cups. Although the currents in the helices are reversed twice in each revolution, they are turned into one direction by means of the pole-changer. From the manner in which they are obtained, they necessarily vary more or less in power in the different parts of the revolution, according to the position of the armature. This primary magneto-electric current has too low an intensity to afford strong shocks. But secondary currents may be obtained by interrupting the primary circuit, as with the galvanic current. These have a much higher intensity, and give powerful shocks. One of the springs pressing on the pole-changer is fixed by a binding-screw into a pillar, and the other in a similar one opposite. They are bent at right angles, and when both the horizontal and vertical portions are made to touch the segments of the pole-changer, the circuit is broken as the armature revolves. The horizontal parts simply bring the two primary currents into one course. For showing the sparks, another wire-spring, fixed in a pillar, is made to play upon steel pins set in the small wheel on the shaft. Shocks are obtained at every part of the revolution; but with a moderate speed, they are most powerful when the legs of the armature are near the magnet. If the motion is very rapid, this difference is less appreciable, and with a powerful machine, the torrent of shocks which then results becomes insupportable. The muscles of the hands which grasp the handles are involuntarily contracted, so that it is impossible to loosen the hold. The shocks are, however, instantly suspended by bringing the metallic handles in contact. The metallic handles are placed in connection with the screw-cups, for the purpose of giving shocks. When these are held in the hands, the arm connected with the negative cup will be found most affected by the shocks. This is a physiological phenomenon, the current producing a greater effect upon the arm in which it flows downwards, in the direction of the ramification of the nerves, than upon the one in which it ascends. The initial secondary is too feeble to afford shocks, so that only the terminal secondary need be taken into account. The intensity of the terminal shock is, how-

ever, constantly varying, according to the position of the armature in respect to the magnet, and the difference in the effect upon the two armatures is not so distinctly marked as with some of the instruments which will be described hereafter. The shocks may be regulated to some extent by varying the speed with which the armature is made to revolve. They are considerably lessened by partially neutralising the power of the steel magnet, by placing an armature across it near the poles; also, by passing the current through a piece of wet cotton wicking, a few inches long, one end of which is connected by a wire with one of the screw-cups on the base-board, from which the handle is removed. By grasping in one hand the handle connected with the other screw-cup, and in the remaining hand the disconnected handle, and touching a short wire attached to this to the wet cotton, the shock is diminished in proportion to the length of the imperfect conductor which the current is obliged to traverse. Slight shocks may be obtained from the primary current, by grasping the metallic handles connected with the screw-cups. The wire which plays upon the pins must be removed, so that the circuit shall not be broken. It is also essential that neither of the springs pressing on the pole-changer should leave the segment which it touches before it comes in contact with the opposite segment. If this is neglected, the circuit will be interrupted at the pole-changer, and strong shocks obtained. When the screw-cups are connected with those belonging to the inner coil of the double helix and electrotome, and the central opening of that instrument is filled with iron wires, secondary shocks of considerable strength will be obtained from the exterior helix whenever the armature is made to revolve. The vibrating wire should be put in motion to break the primary circuit. Bright sparks are at the same time seen in the mercury cups. The magneto-electric sparks are conveniently shown by passing the primary current of the machine through the clock-work electrotome, the vibrating wire of that instrument being set in motion. (Davis.)

The primary magneto-electric current will decompose water or metallic salts. For this purpose the primary current is preferable to the secondary one. With solutions of the metallic salts, the metal is precipitated upon the negative wire, as in the case with the galvanic battery. If the current is reversed, the metal is dissolved off and transferred to the other pole.

The magneto-electrical machine is now used extensively for electro-metallurgic purposes, and also for telegraphing, but for the latter it probably will never supercede the battery.

An improved magneto-electric machine has lately been got up by Daniel Davis. The two straight armatures described in the foregoing machine are used in this one, but they are much shorter. The steel magnets are fixed with the south pole of one above the north pole of the other, at such a distance as just to allow the armatures

to pass between them. These are mounted, one on each side of a vertical shaft, in such a manner that both shall be passing between the opposite poles at the same time. They are made to revolve rapidly by a multiplying-wheel. A pole-changer on the shaft conveys the alternating current in a constant direction to the screw-cups with which the metallic handles are in connection. For giving shocks, the small wheel on the shaft is set with vertical pins, upon which plays an iron or steel wire connected with one of the screw-cups. Brilliant sparks are seen as the wire passes over the pins. The sparks are sometimes half an inch in length. The shocks are stronger than with the machine just described, and the decomposing power considerably greater. (Davis.)

The instrument which is the most used for medical purposes, is that which derives its electricity from the inductions caused by the alternate gaining and losing of the magnetism of electro-magnets. They consist of two helices, the inner one of which is of coarse copper wire, while the outer helix is of fine wire. Both these wires must be well insulated. In these machines the magneto-electric current is obtained, associated with that referable to electro-dynamic induction. Inside of the inner coil there is an electro-magnet, being composed generally of a bundle of soft iron wires. These are used in consequence of their power of gaining and losing their magnetism with greater facility than a solid bar. When the current from the battery is passed through the coil of coarse wire, or the inner one, the iron wires become strongly magnetic, and induce in the outer coil an initial secondary current of great intensity. When the current of the battery is broken, then a terminal secondary is induced in the fine wire, and which flows in the opposite direction to the initial. Thus by a contrivance by which the attractions of a small electro-magnet break the battery current, a torrent of secondary currents is developed in the fine wire surrounding the coarse. These secondary currents possess great intensity, and therefore give powerful shocks. If the wires are entirely withdrawn from the inner coil, then the shocks become scarcely perceptible. These shocks are not magneto-electric, but are wholly electro-dynamic. If a glass tube is put over the iron wires when they are within the helix, it does not interfere with their inductive action. But if a metallic tube is slipped over them, such as a brass one, the inductive action is suspended. The reason why the brass tube neutralises the inductive action of the wires may be thus explained: The magnets induce in the tube a secondary current which flows around it. This secondary current induces a tertiary one in both of the coils. These flow in an opposite direction to the secondary current induced in the coils at the same time by the magnet, and therefore neutralise them. For this reason the cups of the magneto-electric machines are always sawed through, so that closed currents shall not circulate through them, and thus retard those circulating

through the wires. If the terminations of the fine wire coil which surrounds the coarse one are joined together, there will be formed around the magnet closed currents, which will lessen the secondary current in the coarse wire. A metallic cylinder surrounding both helices, will also exert a neutralising effect upon their induced currents. When a bar of iron is placed inside the inner coil in place of the wires, there is formed around its circumference a closed current, or secondary current, similar to that in the brass tube, and which partially neutralises the currents in the wires. It is for this reason that the wires are more available than the solid bar, while the former lose and regain their magnetism with more rapidity than the latter.

By sawing the brass tube through its length, the circulation of the closed currents is prevented, and thus its neutralising effects are destroyed.

If the solid bar is sawed through longitudinally to its centre, then the circulation of the closed currents is prevented, and the neutralisation of the secondaries in the wires does not take place. Still the wires give the strongest shocks, and are therefore generally used for the purpose.

INDUCTION BY THE INFLUENCE OF THE EARTH.

Although the magnetism of the earth induces a current of electricity, still it is so feeble that it is difficult to render it sensible by wire coils alone. If a long wire helix is placed in a vertical plane and revolved, the galvanometer will indicate induced currents. The helix must revolve in the magnetic meridian, and must move with great rapidity, the currents being transmitted in one direction by means of a pole-changer fixed upon its shaft.

If an iron bar is put inside of this helix, then the current becomes stronger. Revolution of an electro-magnet suspended delicately upon two wheels, may be produced by the magnetism of the earth, when the battery current is used for the purpose of giving polarity to the electro-magnet. In this instrument the polarity of the electro-magnet is changed twice during each revolution, and being free to move, the magnetism of the earth moves it around, either vertically or horizontally, depending upon the manner in which the instrument is suspended. These magnets, when constructed with sufficient delicacy, revolve with great rapidity.

PHYSIOLOGICAL ELECTRICITY; AND THE APPLICATION OF ELECTRICITY TO DISEASE.

Thales, who flourished six centuries before the Christian era, was the first to discover that amber is possessed of certain properties which we term electrical. The phenomena which amber manifests

when excited, led this philosopher to suppose that it was animated. Then *Theophrastus of Eresus*, one of the most illustrious pupils of Aristotle, three hundred years after the time of Thales, made the discovery that tourmaline had the property of attracting light bodies after being excited by friction. For ages after that time nothing further was elicited regarding electricity until Dr. Gilbert, of England, published a work on magnetism, in which the attention of the philosophical world was called to several new facts in electricity. But in the year 1746 the leyden jar was introduced, and the surprising effects of frictional electricity became generally known. Its medical powers were then thought to be illimitable, and it was indiscriminately applied to the most opposite diseases. Such empiricism soon caused it to fall into disrepute, and it was not until the commencement of the present century that really scientific men resorted to it as a curative agent of great power.

Frictional electricity is but little used for the purpose of curing disease, although the reports of cases treated at Guy's Hospital, London, would not justify us in entirely excluding that agent from the *materia medica*.

The theory of the electrical machine may be stated as follows : The electricities of the rubber are separated by the friction caused by turning the handle of the machine, or the electricity is said to be decomposed. The positive electricity remains upon the glass, while the negative adheres to the rubber. The rubber would, therefore, soon develop no more positive electricity, if insulated. To prevent this, the rubber is connected with the earth, by which means the supply of positive electricity is kept up and the negative state neutralised. The positive electric portions of the glass coming during its revolution opposite to the metallic points on the conductor, act powerfully by induction on the natural electricities of the conductor, attracting the negative, which being accumulated in a state of tension at the points, darts off towards the cylinder to meet the positive fluid, and thus restores the neutral compound. The conductor is therefore left positive.

Positive electricity is developed on glass, when it is rubbed with a woollen cloth ; and negative electricity is developed upon a piece of sealing-wax, or shellac, by the same process. One species of electricity cannot be produced without a development of the other. If two substances are rubbed together, and produce electricity thereby, one of them will be positively electrified, and the other will be negative.

It has been mentioned that several species of fishes have the power of producing electricity at will. The *Gymnotus*, or electrical eel, is perhaps the most remarkable in this respect. Also the *Torpedo*, which often attains an enormous size, and gives shocks which will prostrate a man. This electrical power appears to be under the dominion of the will of the animal, and is doubtless the sudden

conversion of the nervous into the electrical force. If this be the case, then it is not unphilosophical to suppose that the converse can be attained, the conversion of the electrical into the nervous force.

Besides the fishes alluded to above, there are doubtless insects which possess the power of developing electricity. The hydra, a fresh-water polype, is thought by naturalists to possess the power of giving an electrical shock, as it appears to instantaneously paralyse large worms and other creatures which come within the influence of its long tentacula.

The nervous system of many animals is very susceptible to the influence of a current of electricity. In the case of the frog, and several other animals, the motions and sensations produced by the voltaic current are some of the most delicate tests of its existence. If a strip of silver and another of zinc are brought into contact when touching the thigh of a grasshopper recently killed, the leg will extend and contract, depending upon the manner in which the metals touch it, or are brought into contact themselves.

If the legs of the frog are prepared by removing a small portion of the lumbar vertebrae, with the extremities attached, and the poles of the feeblest battery be applied to them, their contortions will indicate its existence.

These experiments prove that the nervous system of animals is extremely susceptible to the influence of a current of electricity. If the susceptibility of the nervous system is so manifest when such a delicate agent is applied to it, may not that agent exert some effects upon it when in a state of disease, which may alleviate it? The anatomical relations of the nervous system to the electric organs of fishes; the evident exhaustion of the nervous energy during the production of electricity in that organ; the apparently equivalent production of electricity, in proportion to the quantity of the nervous force consumed; the constant direction of the current produced, with its relation to what we may believe to be an equally constant direction of the nervous energy thrown into action at the same time—all induce me to believe that it is not impossible, but that on passing electricity perforce through the organ, a reaction back upon the nervous system belonging to it might take place, and that a restoration, to a greater or smaller degree, of that which the animal expends in the act of exciting a current, might perhaps be expected. So, perhaps, in those organs where nature has provided the apparatus by means of which the animal can exert and convert nervous into electric force, we may be able, possessing in that point of view a power far beyond that of the fish itself, to reconvert the electric into the nervous force. (Faraday.)

From the above language of Faraday it would not seem impossible to convert the electrical into the nervous force, and it was perhaps with such hopes, that the ablest physicians of the present day are

directing their attention to electricity as a potent agent in the alleviation of many of the maladies which afflict the human family.

The remarks of Dr. Channing upon the analogies existing between the nervous force and electricity are so close to the point, that we shall quote them here. The physical agent residing in the nervous system, and also in the tissues, bears a remarkable analogy to electricity in its three principal characteristics—the exertion of attractive force, the control of chemical affinity, and the rapid transmission of impulses. It will be observed that these analogies are much more striking and fundamental than any offered by magnetism or chemical affinity, where electricity exists in other and undisputed combinations with matter. The impulses connected with volition and sensation are propagated along the nervous cords with the same dependence on the integrity of conductors as in the case of galvanism, though with a modified law of conduction. The chemical changes effected by vital force take place under an affinity like that in nature, alone supplied by electricity. We not only find this exerted by the ultimate particles of the tissues, but we have an example of the polar decomposition of common salt taking place between the secreting organs of the stomach and liver, muriatic acid appearing at the one, and soda at the other, in the course of their natural functions. This correlation of electro-chemical powers in different organs is evidently due, not to the vital force in the tissues of those organs, but to the agency of the nerves, supplying them and uniting their functions. The vital force, therefore, in both its manifestations of the nervous system and of the living tissues, modifies existing electro-chemical affinities as by the power of electricity itself. The attractive force developed in muscular and other living tissues, producing the effect of motion, bears a close analogy to the attractive force so suddenly communicated to, and withdrawn from, the particles of magnetisable bodies by electricity.

Whether electricity and the vital force be identical or not, experiment has proven that they bear a very close analogy to each other—so close that the one may be substituted for the other; for we can now say, with Dr. Wilson Phillip, that “we have seen that galvanism is capable of performing all the functions of the nervous power so called.” We know that it is capable of stimulating the muscular movements of animal and organic life, that it will promote secretion and absorption in the proper organs, affect nutrition and influence the capillary circulation, besides exciting all other functions to the full extent of their dependence on the nervous system. (Channing.)

In his remarks upon the effects of galvanism upon the digestive organs and the liver, Dr. Wilson Phillip says that he has repeatedly seen from it the same effect on the biliary system which arises from calomel—a copious bilious discharge from the bowels coming on in a few hours after its employment.

Perhaps there could not be a more striking proof of the stimulative effects of electricity than is effected upon the nerves of special sense. By passing a voltaic current through the nerves connected with vision, hearing, taste, or smell, a flash of light, a sound, a metallic flavor, or a peculiar odor, is at once perceived. Of course these sensations are but the stimulation of the nerves conveying the current, each nerve giving its own special function.

The following statement of the relations of electricity to the nervous system is by Matteucci, and gives perhaps as precise a view of the subject as can be given in the present state of the science. He observes that electricity differs from any other nervous stimulant—1st, in that it excites sensation at one time and contraction at another, according to the direction in which it traverses a nerve; 2d, in that it does not excite a nerve when passing through it transversely; 3d, in that neither contraction nor sensation are produced when its influence upon a nerve is prolonged; 4th, in that it alone has the property of increasing or diminishing the excitability of a nerve according to the direction in which it is made to flow; 5th, in that it has the power of awakening the excitability of a nerve after all other stimulants have ceased to act. Beyond this, however, as might be anticipated, electricity reacts with the vital agent of the tissues, as well as of the nervous system. Thus, when a galvanic current is sent through a limb, in the opposite direction to the motor nervous current, a muscular contraction takes place, which Marianini has called *idiopathic*, or the result of the immediate stimulus of galvanism on the muscular tissue; but when the current is sent in the direction of the ramification of the nerves, a stronger or sympathetic contraction takes place, which is the product of both the electric and nervous stimulus. Thus when the nerve of a frog is exposed, contractions of the muscles supplied by it are only produced when the current flows through the nerve in the direction of its ramifications; but they are produced in a muscle in whatever direction the current flows through its tissue.

It has been observed that there are constantly currents of electricity ensuing between organs deeply seated and those which are superficial. These organs differ both in temperature and in chemical constitution, and therefore they must sustain constant currents, whose existence must exert considerable influence upon their health or disease. Likewise in the organs of secretion, where fluids of different constitution are separated from each other by very thin membranes, there really exist all the conditions necessary to form galvanic currents of considerable energy. These currents must certainly have a tendency to alter or modify the secretions, or to enhance or depress the vital force. For these reasons electricity has been deemed a potent agent for the alleviation of disease, and its application to various forms of maladies is now considered a legitimate department of medicine.

In the year 1844 the writer of these lines instituted a series of experiments for the purpose of transferring substances through and from the human body by means of the voltaic current. In one hand was placed a rod, wet with a solution of the iodide of potassium, and in the other a similar rod, moistened with a solution of starch. In the hand holding the salt of iodine was placed the negative pole of a battery of six of Grove's cups. In the other hand was placed the positive pole. In a few minutes the latter pole was surrounded with a deep-blue iodide of starch. This experiment was varied in several ways, but the same result was obtained, proving the passage of the iodine from the negative pole, through the body, to the positive pole.

A person who had been taking a considerable quantity of blue-pill, for a syphilitic taint, was taken for the next experiment. His feet were placed in a foot-bath which contained some water acidulated with hydrochloric acid. The feet were made to rest upon a plate of copper, polished carefully. The negative pole of the battery was attached to this copper plate, while the patient held the positive pole in his hand. In half an hour the copper plate was coated with what appeared to be a white powder. So thickly was this coat thrown upon the copper, that the impression of the foot, and especially the toes, was left strongly imprinted upon the plate. Upon examining the plate with a magnifying-glass, this white substance was found to consist of innumerable minute globules of mercury.

These experiments were published soon after in the Cincinnati *Daily Commercial* newspaper, and in the September number of Hines' *Herald of Truth* for 1847. Since that time, this subject of the withdrawal of mercury from the system has become agitated, and instances are plenty in which it has been withdrawn from the system. The electrolysis of mercury from the system will prove, in a striking manner, the great benefit which voltaic electricity is conferring upon suffering humanity.

Since the employment of electricity in the cure of disease has been rendered popular, and, we may add, *respectable*, by the able physicians of England, who have devoted their talents and learning to it, there has been elicited much valuable information in regard to its application. It was soon discovered that the direction in which the current was sent exerted an influence upon the result of the application; for that while the current sent in one direction was followed by a curative effect, the current sent in another direction was frequently attended with injury. It was also ascertained that there are certain diseases which require for their alleviation an increase of the electricity circulating in the nerves; that there are others which require a decrease of the electricity existing within the organs, while others require a stronger current which shall produce decomposition.

As this work is devoted more especially to the medical student,

we shall not only give a list of the diseases in which the voltaic current is available, but we shall give with the enumeration of the disease the method of applying the current as prescribed by the ablest physicians. For the remarks which follow upon the treatment of disease by electricity, we are principally indebted to Dr. R. M. Lawrence, of Berlin. The therapeutic application of electro-galvanism requires no less consideration than that of any other powerful remedy. In applying a current of electricity to the human frame, the object is to act upon the static electricity of the body. By the application, for instance, of the positive pole, the corresponding electricity contained in the body (which is in a state of equilibrium) is set free, and circulates in large quantities in the nerves, the combination of the positive current from the apparatus with the negative of the body, forming a neutral compound. An opposite result, of course, follows the application of the negative pole. The normal current circulating in the nerves should be increased when there is a deficiency of electricity in the system, and increased when there is an excess. In health there exists a certain quantity of the electric fluid in the nerves, which is increased or diminished by disease. With regard to the use of this remedy, it is important to observe that, in treating the diseases enumerated in the first and second division, the application ought not to be painful. The sensation produced by the passage of the current should be no stronger than the slight pricking similar to that felt in a limb which is asleep. When it exceeds this, the application is not attended with so much benefit.

The diseases mentioned in the third division require to be acted upon more powerfully—and the closer approximation of the electrodes causes greater pain; but the application being merely local, it is not followed by any unfavorable constitutional symptoms.

As a general rule, the application of the electric current to the diseases named in divisions first and second should not be continued longer, when only applied to one part, than from ten to fifteen minutes; but, should it be thought desirable to apply it more generally, the length of the application may be extended to from twenty to thirty minutes. Persons of great nervous susceptibility will sometimes be met with, who cannot bear it for so long a time.

One application a day is usually sufficient; but there are cases which derive benefit from a more frequent use of the remedy, and others again who require it only on alternate days. The feelings of the patient must be consulted in regulating the strength of the current; but the weakest power should be commenced with, and gradually increase the strength so long as the application does not induce pain.

In those cases which require an increase of electric activity to supply the deficiency of the current in the nerves, the *negative* electrode must be placed either on the spinal column, the forehead, the

temples, or nape of the neck; and the positive applied to the feet, hands, or abdomen, according to the part affected, which it is necessary to bring as much as possible under the direct influence of the electric fluid.

In those cases which require the quantity of electricity circulating in the nerves to be diminished, the positive pole must be placed on the back, the negative on the part affected.

In the diseases alluded to in the third division, where the local application of the electric current is to produce chemical decomposition, no indications can be given; and the mode of applying the current must be left to the judgment of the student.

The electric current can be more advantageously and conveniently applied by another than by the patient himself, as the physician is able to employ a larger quantity of the fluid, with no more sensation to the patient than the slight crackling he would experience on rubbing a cat's back the wrong way of the coat. When applied in this way, one electrode is placed on the patient, the other is grasped by the operator, who with the back of the fingers of the disengaged hand gently rubs the part affected.

Although frequently very decided relief is obtained by a single application of electricity, it must not be looked for as an invariable result. Chronic affections of long standing require perseverance in the continued use of the remedy; and there are few cases which, if they do not absolutely yield to its influence, at least derive some benefit from it. We do not advocate this remedy to the disparagement of other modes of treatment, but regard it as a very important auxiliary; and our own experience bears testimony to its value in combination with medicine, where it is probable that either tried singly would have failed.

DISEASES IN WHICH THE FREE ELECTRICITY IN THE NERVES SHOULD BE INCREASED.

General Debility.—The employment of the electric current in this malady is invariably attended with benefit. It must be applied chiefly to the back when the debility is general, and to, or as near as possible to the part affected, when it is more local. At the same time, attention to the diet, combined with judicious medical treatment, will materially assist the cure.

Incontinence of Urine.—Apply one pole to the bladder, whilst the other is applied over the pubes.

Paralysis of the Bladder.—Electro-galvanic currents have been successfully applied to the bladder, where from over-distension, during labor, it has lost the power to expel its contents, requiring the daily use of the catheter. The electro-galvanic current speedily restores the organ to the dominion of the will. In hysteria, paralysis of the muscular fibres of the bladder, or spasm of its sphincter,

sometimes occurs, which an electro-galvanic current will succeed in removing.

Amenorrhœa.—(*Absent and suppressed Menstruation.*)—There are two very distinct classes of amenorrhœa, one where the menses have never appeared, and which has received the name of absent menstruation; the other, in which having continued regularly for some time, they have ceased: this is called suppressed menstruation.

In those cases where no congenital malformation exists, the application of the electric current will always be attended with success, even after all the usual remedies have been tried in vain. In this disease it is essentially necessary to combine medical with electrical treatment. The first object is to strengthen the system by a well-arranged, nutritious diet, moderate use of wine, exercise, and some preparation of iron; and when we have succeeded in improving the general health, but failed in producing the menses, we must have recourse to those remedies which possess a specific power over the uterine secretion, and the one I have never found to fail is electricity.

"In electricity," observes Dr. Bird, "we possess the only real direct emmenagogue with which the experience of our profession has furnished us. I do not think I have ever known it to fail to excite menstruation when the uterus was capable of performing this function. Disappointment will, however, most certainly result, if we have recourse to electricity, merely because a girl does not menstruate; we must never lose sight of the fact, that, after all, the large majority of cases of amenorrhœa depend upon an anemic condition, and that the patient does not menstruate simply because she has no blood to spare. Nothing can be more ridiculous than applying electricity, or any other local stimulant, to the uterus, when chlorosis exists; the first great indication will be to restore the general health, give iron to make up for the previous deficiency of that element in the blood, and then, and not before, think of stimulating the uterus. A few shocks transmitted through the pelvis, seldom, if ever, fail in effecting menstruation." We have repeatedly known the catamenia, although previously absent for months, appear almost immediately after the use of electricity; in more than one case the discharge actually appeared within a few minutes.

Flooding during Labor.—The voltaic current has been used with the greatest success in flooding during labor, and for the purpose of causing a contraction of the uterus. In numerous cases which have been tried, the application of the current induces contraction when ergot has entirely failed. For this purpose the current should be sent both along the longitudinal and transverse axis of the womb. The great advantage of the voltaic current is its speedy action, for while the ergot, when it does act, is frequently an hour or more in doing so, the voltaic current produces almost instant contraction. Such is the value of the voltaic current in labor, that Dr. Dorrington, of England, said, in his address before the Manchester Medical

Society, that "Galvanism is one of the most valuable additions which has been made to our obstetrical armamentarium in modern days."

Hypochondriasis and Hysteria.—Electric currents have been applied in the treatment of these diseases with the most satisfactory results. It is first necessary to restore the energy of the brain and nervous system, and to improve the general health. The first application is usually followed by some improvement, but the treatment must be continued for two or three weeks to produce permanent benefit. The application should be made by rubbing the part to which the electric fluid is applied, either with the hand, or by the application of a sponge.

Indigestion.—The beneficial influence of the voltaic current is experienced after a few applications by the removal of the nausea, distension, weight, oppression, and spasmodic pains of the stomach, the general languor and debility, and by giving tone to the stomach. The current is passed through the region of the stomach. The applications of the poles must be through sponges wet with water or spirits of wine.

Constipation.—The voltaic current is a safe, gentle, easily-regulated means of acting on the bowels to any required extent, whether the intention be to produce brisk evacuation, or to imitate the process of nature. The current should be passed from the nape of the neck to the abdomen, and across the abdomen in the direction of the transverse colon.

Aphonia, or Loss of Voice.—The passage of the voltaic current through the larynx, in the treatment of this complaint, is attended with the most gratifying results. At the same time the general health must be restored by the use of tonics, &c.

Deafness.—The voltaic current is of great benefit in all cases in which no organic changes have taken place. Also in nervous deafness, when the infirmity proceeds from general debility, and varies in degree with the weather and general health of the patient. The application should be made with great care, and should it produce a humming noise in the ear, the patient may be sure that it is doing good.

Amaurosis.—The impairment of vision, which is the first and most prominent symptom of this disease, arises from some change in the retina, optic nerve, or brain. It may be caused by long-continued exertion of the eye in viewing minute objects, exposure to glaring light, by an exhausting disease, by certain narcotico-acrid poisons, or it may be a consequence of organic change, inflammation, or concussion. This disease has been treated most successfully by the voltaic current, but the application requires to be conducted with great care, and never should be attempted by those unacquainted with the minute anatomy of the delicate organs which are the seat of the disease. This disease has been successfully treated by

puncturing the frontal nerve and the superior maxillary nerve. Many cases of imperfect amaurosis, with or without paralysis of the muscles of the eye, have been relieved in almost every instance. It has been proved that the puncture of the orbital branches of the fifth pair of nerves is by no means dangerous.

Paralysis.—When this disease proceeds from any other cause than congestion or cerebral mischief, it is invariably benefited by the voltaic current. In cases of long standing the improvement progresses slowly, in consequence of the new tissue which has been deposited and become organized, but has never contracted at the will of the patient.

Asphyxia, or Suspended Animation.—Electricity has yet another application in connection with human suffering, still more wonderful than that which it receives as a remedy for pain and disease. Through its agency the feeble flame of life has been revived when, to all appearances, it was hopelessly extinguished. It has been used to restore suspended animation in persons apparently dead from drowning, narcotic poisoning, or the use of chloroform.

Galvanic excitation of the diaphragm has been proved to be most valuable in threatened suspension of the respiratory act after the use of anæsthetic agents. Practice exemplifies in a most striking manner the utility of galvanism or electricity in many cases, as a resuscitative agent. The galvanic current has not only the effect of producing a marked improvement in the pulse and respiration, but they also produce dilatation of the pupils, and complete return of consciousness. Cases are constantly appearing in the medical papers of even the youngest, who have been saved by the use of this powerful remedy in cases of narcotic poisoning. The first care should be to remove as much as possible of the poison from the stomach; but this done, the real difficulty of the case begins. The great peril besetting the patient is the fatal indulgence of sleep; and this danger was averted under the old form of treatment by many expedients which were of necessity rough and cruel. Modern science supplies more effectual and desirable means in the stimulating powers of electricity. The electric current must be applied by placing the negative electrode at the nape of the neck, and the positive electrode at the pit of the stomach; if this does not act with sufficient power, insert a needle between the eighth and ninth ribs on either side so as to reach the diaphragm, and then allow the current to pass. The current must not be applied too strongly, or otherwise we may defeat the object we have in view.

DISEASES IN WHICH THE FREE ELECTRICITY IN THE NERVES SHOULD BE DECREASED.

Profuse and painful Menstruation.—The general symptoms in profuse menstruation are exactly those we should anticipate from

the continuance of a debilitating discharge, viz., exhaustion, languor, and dislike of exertion, weakness across the loins and hips, paleness of the countenance, headache, throbbing of the temples, and giddiness. In painful menstruation there is most frequently defective secretive power, accompanied by severe pain, which is the distinctive symptom of this disease. The amount of pain varies very much; it may be moderate, lasting for a few hours each time, or it may be so severe as seriously to derange the health of the patient. This disorder is generally confined to those of a nervous temperament, and of a thin, delicate habit of body. The monthly paroxysms present all the characters of neuralgia. From the statements which I have already made concerning the effects of electricity, it will be evident, after the above short description of the main symptoms of these diseases, how much benefit would result to the patient from the voltaic treatment.

Induction of Uterine Contraction.—The voltaic current is capable of inducing uterine action *de novo* in those cases in which, from the peculiar formation of the pelvis, it is not possible for the woman to bring forth a living child at the termination of the nine months, and in which we wish to bring on artificial premature labor. Also in those cases where uterine action is insufficient from debility, and the pains after awhile cease altogether, the electric current is capable of exciting uterine contractions, and of bringing labor to an end in a shorter time than any medicine we know of. And, lastly, that its application is never attended with any injurious consequences.

Muscular Contractions.—Contractions of various muscles take place at different periods of life, and may produce either permanent deformity, or may be relieved by removal of the cause which gives rise to the contractions. The muscles become wasted and stiffened from inaction or after injuries, fever, exposure to cold, or some affection of the nerves. The affected limb is cold, numb, imperfectly nourished, and ceases to grow in proportion with the other parts of the body. The flexor muscles often become so rigid as to produce dislocation of the bones to which they are attached. The voltaic current will in most cases completely restore the affected limb.

Writers' and Sempstresses' Cramp of the Hands.—Many unavailing remedies have been tried in the treatment of this affection, the continuance of which produces a contracted state of the fingers and hands, depriving the individual of their use. The voltaic current will, in a short time, accomplish a cure.

Rheumatic and Arthritic Pains.—In these diseases the voltaic current is always attended with relief. It should be applied at least once a day, but the current should not be too strong.

Neuralgic Pain of the Side in Hysteria.—This pain, so common in females of the hysterical constitution, which is oftener complained

of in the left than in the right side, and has been so frequently ascribed to inflammation, and actually treated with leeches, blisters, and blue-pill, when no such inflammation existed, will quickly yield to electro-medical treatment.

Headache.—Headache is a symptom of almost all acute and chronic diseases of the brain, as well as a distinct functional derangement of very frequent occurrence. The cause of headache should be carefully inquired into, and in those cases where the electric current is indicated, speedy and positive relief will be derived from its use. Hemisrania is simply headache confined to one side, and occupying generally the brow and forehead, but sometimes affecting, very exactly, one moiety of the head. It is attended with sickness, and is frequently periodical, and recurring at variable intervals, but always lasting a certain time, and then subsiding. It is produced by various causes, almost all of which tend to debilitate the system. In the treatment of this complaint, the patient derives signal benefit from the combination of electrical and medical treatment.

Tic Douloureux.—We now come to those cases in which a single part, or nerve, is the seat of pain. The face is the most exposed, and therefore most frequently affected; generally, the parts supplied by the facial branches of the fifth pair of nerves—nerves of sensation. The torture occasioned by this dreadful affection is sometimes excessive. The sufferers speak of it as anguish that is scarcely endurable, and you see in their quivering features and restless limbs that the acute bodily pang is, indeed, hard to bear. This affection may continue for years. The fact that there exists so great a number of specific remedies for this complaint, each of which has been known or supposed to accomplish a cure, affords one of the strongest evidences of the intractability of the disease. In this complaint we see the advantage of the voltaic treatment, and in those cases in which medical treatment has been employed without avail, the combination will prove most gratifying to the medical attendant and beneficial to the patient. The application of the galvanic current produces, in many cases, a profuse perspiration. On its appearance there is a marked improvement and decrease of pain, and the patient, who has been deprived of sleep for nights, will go home and sleep soundly for hours.

Cramp of the Stomach, Chest, and Limbs.—The electric current, when properly applied, is followed by immediate relief in all spasmodic affections—a single application frequently effecting a permanent cure. Many cases of asthma have been relieved by the galvanic current, and a considerable shortening of the periodic attacks, when present, will be effected through its agency. Dr. Wilson Phillip says, "I have employed galvanism in many cases of habitual asthma, and almost uniformly with relief." In cramps of the calves of the legs, when all the usual remedies have been tried,

and failed, the application of the current for a few minutes will act as a charm in removing the spasm and pain.

Chorea.—This is a spasmodic disease essentially belonging to the nervous system. The ordinary movements of the body are in some degree under the direction of the will; but it sometimes appears as if some other person opposed the will, and excited them when they are not wanted. When the body has been wasted, the mind apparently giving way, and the disease proceeding unchecked by other means, this agent will frequently effect a cure. The following is the result of thirty-seven cases treated at Guy's Hospital, London. Thirty were completely cured, five were relieved, and two uncured. Cases of rheumatic chorea are generally obstinate, but still appear to yield to the voltaic treatment. Dr. Bird has observed that the more extended his experience the greater his confidence in this remedy, and he cannot otherwise account for its failure in the hands of others than by attributing it to the mode of application. He says that most satisfactory results have followed when he has suggested its use in private practice, in cases which had run the gauntlet of all kinds of treatment in vain.

Tetanus.—This disease is characterised by an involuntary, long-continued, violent, and painful contraction of the voluntary muscles of various parts, or of nearly the whole body. The muscles that seem in general to be the earliest affected, are those of the neck, jaws, and throat, and at length the jaws close with great firmness. Relief has frequently followed the application of voltaic electricity, and in several instances perfect cures have been effected by this agent. Two cases are mentioned by Dr. Lawrence, in which immediate benefit resulted from a few minutes' application, and in both the continued use of it effected a cure within a fortnight.

Epilepsy.—There are a number of cases on record which have been cured by the voltaic current. The application requires to be continued with perseverance for a considerable length of time, when, in the majority of cases, a cure will be effected. The younger the patient, and the more recent the disease, the greater will be the chance for recovery.

Hydrophobia.—A well-authenticated case of this dreadful malady, which was entirely relieved by the voltaic current, is published in a "Report presented to the class of the Exact Sciences of the Academy of Turin." The patient was laboring under all the dreadful symptoms of hydrophobic madness, when the application of the voltaic current entirely relieved him. The battery employed consisted of fifty pairs of plates of zinc and silver, intermixed with fifty pieces of pasteboard, moistened with a solution of muriate of ammonia. The voltaic current has not been tried in this country for hydrophobia, but the success which has attended its administration in Europe would certainly justify its application in this country.

DISEASES IN WHICH ELECTRO-CHEMICAL DECOMPOSITION SHOULD BE PRODUCED.

Experiment has long since proved the influence which voltaic electricity exerts over affinity; and to such an extent that compound bodies, in which the components are united by the most powerful affinities, are not only decomposed, but their elements are transported to great distances, and are even carried through substances without combining, to which they nevertheless have a strong attraction, and to which they otherwise would have united. Sir H. Davy, having placed his fingers, previously well wetted in distilled water, in the positive part of the voltaic circuit, phosphoric, sulphuric, and muriatic acids rapidly passed into the water from his body. On making a similar experiment at the negative side, fixed alkali made its appearance. "Now," says Becquerel, "since acid and alkaline substances can thus be separated from their combinations in the living body by means of electric power, there is reason to believe that by the same means may be introduced into the living body different substances capable of reacting on the organs in different pathological cases." Dr. Fabre Palaprat has made some experiments which seem to promise great results, if the subject be sedulously followed up by the profession. They were as follows: After having dried as much as possible both arms of a woman, he applied to one of them a compress soaked in a solution of iodide of potassium, which he covered with a plate of platinum, in communication with the negative pole of a pile formed of thirty elements, and charged with a liquid adequate to produce decomposition. He placed on the other arm a compress moistened with amidine, which, being covered with a plate of platinum, was made to communicate with the positive pole. In a few moments the amidine had assumed a blue color, clearly proving that the iodine has been transported through the interior of the body, since the skin, which was sufficiently dry, could not give passage to a current. In Davy's celebrated paper on "Some Chemical Agencies of Electricity," read before the Royal Society, 20th November, 1806, the following experiments on the passage of acids, alkalies, and other substances, through various attracting chemical menstrea, are described:—"An arrangement was made, consisting of three vessels: solution of sulphate of potash was placed in contact with the negatively electrified point, pure water was placed in contact with the positively electrified point, and a weak solution of ammonia was made the middle link of the conducting chain, so that no sulphuric acid could pass to the positive point in the distilled water without passing through the solution of ammonia; three glasses were connected together by pieces of amianthus. A power of 150 pairs was used. In less than five minutes it was found, by means of litmus-paper,

that acid was collecting round the positive points; in half an hour the result was sufficiently distinct for accurate examination. The water was sour to the taste, and precipitated solution of nitrate of barytes. Similar experiments were made with solution of lime and weak solutions of potash and soda, and the results were analogous."

It appears, therefore, that the constitution of the fluids of the body may be altered, certain principles may be withdrawn, and the ratio of the remaining principles may be changed. "In the same manner," observes Dr. Donovan, "a new mode of entrance into the human body of active remedial agents is indicated, more quick, more direct, more certain, than any other known, without the risk of being injured or altered by digestion, or of being eliminated by excretion."

We may profit by these experiments, and thus by acupuncturation apply our remedies directly to those parts we desire to act upon, when we find that the internal application proves inefficacious.

In the following diseases we endeavor to effect their cure by inducing electro-chemical decomposition in the part affected, founded on the knowledge of the chemical action of the two poles.

On passing a current through albumen, it coagulates around the positive pole, but none collects around the negative pole. This coagulation is due to the chemical action of the acids, which are separated at the positive pole by the action of the current. At the negative pole, on the contrary, alkali is separated, which, as is well known, dissolves albumen.

Rheumatic Effusion into the Joints.—No part of the body is more frequently diseased than the membrane which secretes the synovia by which the joints are lubricated, and which forms a sack, having no external opening.

When a joint is distended with fluid, we generally find that there is also pain and inflammation, which causes an increase of the secretion from the surface of the synovial membrane. Cases do, however, occur, in which a joint is distended from an increased quantity of fluid collected in its cavity, unattended by pain and inflammation. It is presumed that this proceeds either from the diminished action of the absorbents, or from the increased action of the secreting vessels. Inflammation of the synovial membranes is a constitutional affection when the system is under the influence of rheumatism. It is very often caused by cold, and attacks the knee more frequently than any other joint, because it is the most exposed to the influence of the weather. The inflammation, when confined to a single joint, is generally more severe and of longer duration, than when several are affected.

When the inflammation has subsided, the fluid becomes absorbed, and in most cases the joint returns to its natural size and mobility, though in some, stiffness and swelling remain. In this latter case the patient is very liable to a recurrence of the disease, either from

exposure to cold, too much exercise, or derangement of the general health.

When the inflammation is connected with rheumatism, the same treatment as that employed in that disease will be found beneficial, especially the wine of colchicum.

In those chronic cases where there is considerable stiffness and swelling arising from some constitutional affection, it is first necessary to attend to the general health; to promote, by gentle exercise, a moderate degree of perspiration, which is extremely difficult, as the skin is usually dry and harsh: and to avoid raw fruit, acids, and whatever is likely to turn acid on the stomach, to which there is a great tendency. The bowels should be regulated by warm aperients. These patients generally derive much benefit from a combination of wine of colchicum, iodide of potassium, and bicarbonate of potash.

The application of the voltaic current to joints which are stiff and distended with fluid, will succeed in rendering them supple, and its continued use will effect the absorption of the fluid. The current must only be used when stimulating applications are indicated, over which it has the great advantage of being often repeated without losing its influence on the part.

Opacity of the Cornea and Leucoma.—Opacity of the Cornea may result from adhesive inflammation and effusion of fibrine between its layers, or between it and the conjunctiva. Leucoma is produced by a loss of substance, and its resulting cicatrix.

The voltaic current should be applied in the following manner: A sponge connected with the negative pole of the battery should be placed over the opacity, and a strip of silver connected with the positive pole must be placed on the tongue. Instead of the sponge connected with the negative pole, the latter pole may be connected with the eye-bath, a small instrument invented for the purpose, by Dr. Channing, of Boston. The patient will experience a pricking, burning pain in the eye, the conjunctiva will redden, and some lachrymation will be produced; but these effects will quickly subside on applying cold water. If the opacity begins to break up under the application, it will quickly disappear. The current appears to act more beneficially in those cases where the effusion has taken place between the layers of the cornea, and has not become organised.

Paralysis of the Iris.—One pole of the battery should be placed on the eye, using the sponge for that purpose, while the other should be applied to the back of the neck. The application quickly removes the pain, and causes the pupil to contract and freely respond to the stimulus of light. The application of the voltaic current, in the hands of Dr. R. M. Lawrence, to the paralysis of the iris, was attended with the most successful results.

Cataract.—This disease implies an impairment or weakness of sight, produced by a partial or general opacity of the crystalline lens, or its capsule.

Elderly persons are most subject to this disease, but it may occur at any age, and children are sometimes even born with it. Inflammation, or such injuries as give rise to it, may produce cataract; but it is also sometimes consequent upon an injury which is not attended with any appearance of inflammation. In the aged it seems to proceed from defective nutrition.

We have mentioned the effect of the two poles on albumen, and the success frequently following the application in cases of opacity of the cornea; and we therefore would suggest a trial of the voltaic current in such cases as cannot be relieved by any other known mode of treatment, before the issue of an operation is hazarded.

Ecchymosis.—The black and blue discoloration following a bruise, or contusion, is caused by the escape of blood from the minute vessels into the cellular tissue, and is called *Ecchymosis*. A black eye affords an example. The treatment is regulated by the severity of the bruise; but when there is no inflammation, we employ means to promote the absorption of the effused fluids. The most satisfactory results generally follow the application of the galvanic current, which acts as a powerful stimulant to the absorbents in quickening capillary action.

Nævus.—Nævi may be seated in the skin, or under it, in the cellular tissue. The superficial nævi, or mother-marks, frequently remain stationary during life; but sometimes they have a disposition to grow after birth, and the skin over them being so exceedingly thin, profuse bleeding is apt to occur from the slightest abrasion, which renders it expedient to remove them. The subcutaneous nævi may remain for a time stationary; but their tendency is to enlarge, and distend the skin, which at last bursts, and the patient's life may be endangered by hæmorrhage. In females this tendency is greatest at the menstrual periods. There are several methods of treating this disease, but none of them, in spite of every precaution, are unattended with danger. In consequence of some cases of fistula in ano, and hæmorrhoids, reported in the *Lancet* of 1852, as having been successfully treated by platinum wires made red-hot by a galvanic battery, Mr. Hilton, of Guy's Hospital, determined to apply this plan of cutting and searing at the same time upon a nævus of the flat kind, about the size of a crown-piece, situated in front of the ear of a child two months old. The operation was performed with Cruickshank's battery, and a very thin wire, which it was at first intended to tie around half of the tumor; but the wire ran so easily through it that the whole was immediately removed, and the parts quickly cicatrised. This was found to be a quicker method of removing nævi than the ligature, and just as secure, since hæmorrhage rarely followed. There can be no question but that the electric cautery will supersede every other application of intense heat to the human frame. Its manageable character, by which the temperature may be raised to the nicest point, and its duration reg-

ulated to the smallest portion of time, gives it a very decided advantage over all other methods whatsoever. The electro-thermal can-
 tery may be of any magnitude, beginning with the finest platinum
 wire, and can therefore be applied to all parts, and used under all
 circumstances. For instance, to stop the bleeding of a tooth when
 other means have failed, a bent wire might be introduced into the
 cavity, and the cavity instantaneously destroyed by passing the gal-
 vanic current through the wire. In using electric heat it is neces-
 sary to guard against the fusion of the wires: this, however, may
 always be obviated by trying the experiment with the same length
 of wire prior to its application to the human body.

Stricture of the Urethra.—In this complaint the galvanic cur-
 rent is an efficacious remedy, and very little pain attends the appli-
 cation. After the urethra has been examined with a common plas-
 ter bougie, to ascertain the exact position of the stricture, a metallic
 sound, covered with gum-elastic, and having a conical silver point,
 should be very gently introduced into the anterior part of the stric-
 ture, and then connected with the negative pole of the battery, the
 positive pole being placed in the hand or elsewhere. The applica-
 tion should be made daily, using each time a larger instrument, and
 allowing the current to flow ten to twenty minutes, according to the
 feelings of the patient. Eight or ten applications have usually
 proved sufficient. This mode of treatment will be found of essen-
 tial service in neglected cases, when the urethra for some extent has
 become converted into a thick gristly cartilaginous mass.

Calculus in the Bladder.—Uric acid calculi can be dissolved
 by the aid of electricity at the rate of from two to nine grains an
 hour. Phosphatic calculi can be dissolved at the rate of from two
 to twenty-five grains an hour. Calculi, consisting of oxalate of
 lime, prove to be far less soluble, and can be dissolved only at
 the rate of half a grain to two grains an hour. At present, me-
 chanical force is applied to the surface of the calculus, and the stone
 is passed in fragments; but by the aid of electricity, chemical force
 is set up at the surface of the stone, and it will be passed in solution,
 or as an impalpable precipitate. Every one must acknowledge the
 advantages of a method which will remove a calculus without pain
 or injury to the bladder, rendering an operation unnecessary, which
 is frequently followed by fever, inflammation of the bladder, or re-
 tention of urine, from the lodgment of a fragment of the stone in
 the urethra.

Chronic Glandular Tumors.—These are met with in weak, scrof-
 ulous constitutions; they are at first perfectly indolent and painless,
 and may remain for years stationary, or slowly enlarging. Their
 absorption should be promoted by external applications; and the
 general health, at the same time, must be improved by every possible
 means. The poles of the battery must be so applied that the elec-
 tric current passes immediately over them; or when they prove in-

tractable, medical agents should at the same time be introduced by amputation, as before described.

Ulcers.—There are many varieties of ulcers, each requiring different treatment; and the propriety of employing electricity must be left to the judgment of the medical attendant, who should bear in mind its electrolytic, thermal, and stimulating power, which may be applied in all cases where the healing process is imperfect. Electricity has been applied to old indolent ulcers, with varied success, but on the whole the results have been satisfactory. When an ulcer presents an indolent or lardaceous base, this unhealthy base is generally destroyed, and the surface becomes a healthy granulating one after a few applications of the battery. None of the accepted modes of treating ulcers are found so capable of uniformly producing a rapid growth of healthy granulations as galvanism. Great changes are frequently effected in twenty-four hours in the condition of ulcers. At one dressing they are seen to be deep, cup-like excavations; at the next, the granulations have nearly reached the surface; and after another day the surface has been level with the skin, the granulations uniform, and the well-known marginal blue rim, announcing the commencement of cicatrisation, has appeared. When this point is attained it is better not to apply the battery again, but to employ simple water-dressing.

In cases where several ulcers exist upon a limb, and the zinc is applied to a superior, and the silver to an inferior one, or to denuded surfaces, all the ulcers situated in a direct line between the two plates improve in appearance, become healthy sores, and cicatrise, while those on either side of the current remain unaltered, and sometimes degenerate. In two cases in which we have repeated this experiment, the result agreed with what has just been stated. Dr. Cruicell has healed in this manner primary syphilitic sores in three days.

Cancer.—The disease known by the name of Cancer is divided, according to the consistence of the morbid growth, into hard and soft cancer.

It is often hereditary, and may occur in any part of the body, but most frequently attacks the womb, female breast, stomach, and liver.

Cancer is supposed sometimes to depend on some perversion of nutrition, in consequence of which the lymph which exudes through the capillaries forms an abnormal tissue with the properties of a malignant growth; and sometimes to proceed from a blow or external injury, which, however, can only be regarded as an exciting cause, not capable of bringing on the disease unless there exists a constitutional tendency to its production.

In the commencement, the cancerous growth is usually indolent and painless; but, as the disease advances, it becomes affected with severe lancinating pain. It may remain stationary for years, or increase slowly in size; but there are cases in which it spreads with

frightful rapidity, eating away adjacent parts. The skin at length ulcerates, and a foul and repulsive sore breaks out, which secretes an excruciating and offensive discharge. Frequent hæmorrhages now take place, and the patient soon dies, worn out by the pain and irritation of the disease.

Prof. Müller has discovered that the matter, in all the varieties of cancer, consists of very minute cells; that the original tumors enlarge and extend themselves by the developement of new cells; and that, occurring in one part, they are prone to appear in other parts.

With regard to the cells of animal bodies, one of the most wonderful and extraordinary results which Dr. Lawrence has observed, is the action of electricity derived from the intermittent current of the various forms of electro-magnetic machines.

When a frog's foot is arranged in the field of the microscope, and the intermittent current is directed through the animal, the circulation instantly stops, as if by magic. The current in the veins, indeed, seems slightly to retrograde, though it still continues its course for a short period in the arteries—the whole effect giving the appearance of all the corpuscles having a tendency to be drawn into the capillaries.

In consequence of the corpuscles being drawn into the capillaries, an engorgement of them results. When, however, the current is withdrawn, the blood moves again more rapidly than before, but is instantaneously stopped when the current is renewed.

The action of the intermittent current is as decided upon the lymph corpuscles as it is upon the common corpuscles; for, although ordinarily they run their course at a very different rate from the common corpuscles, they are stopped as suddenly by the intermittent currents. The interference with the circulation of the lymph corpuscle in the capillaries is of more importance than that of the common corpuscle; because, crawling along the side of the vessel, and apparently in contact with it, it is manifestly less acted upon by a *vis a tergo* of the heart's action.

When the continued current is employed instead of the intermittent, the experiment is, perhaps, rather more difficult; yet, if the current be passed completely through the body, precisely the same result occurs. Dr. Lawrence has seen the current absolutely stopped from the feeble current of a dozen pairs of plates.

The bearing of these experiments is in the highest degree important, for it shows that, in whatever process of the body blood is necessary, there the electric force must have an influence. As it is manifest that the circulation of the blood affects more or less every operation of the body, we need hardly state that the experiment demonstrates the importance of electricity as a therapeutic agent.

The application of a piece of metal to an open cancer, which is in connection with a voltaic battery, will produce, after a certain time, a coagulated crust over the surface; and, when this slough

has separated, there will be a healthy sore. The fetid smell, the constant, severe pain, and the hardness, will be greatly relieved. By this means schirrous masses may be removed without loss of blood, owing to the coagulating power of the positive pole—and, indeed, it will be found a most efficacious remedy in hæmorrhage. An Electrolytic Institute has been formed at Moscow, under the direction of several medical men, who report to have cured sixteen cases of cancer, and to have removed the whole of a female breast, without the use of the knife or the tying of the artery.

The Electric Moxa.—The electric moxa is an excellent method of producing a persistent discharge, unattended by the pain which causes the issue or seton to be regarded by the patient with such extreme apprehension. A blister the size of the intended issue is put on the required place. When this is taken off, two small plates, the one of silver, the other of zinc, placed a few inches apart, and connected by a clean copper wire, are applied, after removing the cuticle raised by the effused serum. They must then be covered with the common water-dressing and oil silk. In forty-eight hours the surface beneath the silver plate will be found to be healed; but beneath the zinc plate there will be an eschar, which, when it has separated, will leave a healthy granulating sore, freely discharging pus. The action of the electric moxa is thus explained: The saline ingredients of the fluid, effused on the surface of the blisters, are decomposed; the sodium of the common salt, being set free at the silver plate, becomes soda by oxidation; the chlorine evolved at the zinc plate forms chloride of zinc, which, by its escharotic action, produces the sore. The patient suffers none of that dreadful torture consequent on the use of caustic potash.

THE MAGNETIC CONDITION OF ALL MATTER.

All liquid and solid substances are subject to magnetic influence. Bodies may be divided into two great classes—the *Magnetic* and the *Diamagnetic*. The former class includes all those bodies which exhibit the well-known phenomena of ordinary magnetic attraction and repulsion; being attracted, when in their natural state, by either pole of a magnet, and when shaped into bars or rods, and suspended between two opposite magnetic poles, pointing *axially*, that is to say, in a straight line between them. The bodies belonging to this class are all metallic (including oxides and salts), viz., iron, nickel, cobalt, manganese, chromium, cerium, titanium, palladium, platinum, and osmium. The magnetic properties of iron, nickel, and cobalt have long been known.

The second or diamagnetic class includes all liquids and solids, both organic and inorganic, which do not belong to the magnetic class. The law which governs the action of magnets on these bodies is as follows: A particle of a diamagnetic body placed in the neighborhood of either pole of a magnet is *repelled* by that

pole. Hence it follows that a bar of any diamagnetic substance, suspended by its centre midway between two magnetic poles, will point *equatorially*, that is to say, at right angles to the straight line joining the two poles, that being the position in which every part of it is at the greatest possible distance from each of the poles. And if its centre be placed on either side of the axial line, the whole bar will recede from that line, placing itself at the same time equatorially. A globe or cube does not point, but exhibits the simple phenomenon of repulsion. If two small balls of any diamagnetic substance be suspended between the two magnetic poles, they will be driven towards one another, as if they were actuated by mutual attraction. The position which a bar of any substance takes up when suspended horizontally between two magnetic poles, furnishes the best means of determining whether it belongs to the magnetic or the diamagnetic class. If it be magnetic, it will place itself axially; if diamagnetic, equatorially.

The diamagnetic force cannot be perceptibly developed without the use of exceedingly powerful magnets. Electro-magnets answer the purpose best, but large permanent magnets may be used. Bismuth appears to be the most powerfully diamagnetic of all substances; then follows phosphorus, antimony, heavy-glass. Among the metals, the order of diamagnetic energy appears to be as follows: Bismuth, antimony, zinc, tin, cadmium, sodium, mercury, lead, silver, copper, gold, arsenic, uranium, sodium, iridium, and tungsten.

Air and other gases exhibit decided magnetic and diamagnetic relations. The following gases exhibit diamagnetic properties with regard to atmospheric air: Nitrogen, hydrogen, carbonic acid, carbonic oxide, coal gas, olefiant gas, sulphurous acid gas, hydrochloric acid gas, hydriodic acid gas, fluoride of silicon, ammonia, chlorine, nitrous oxide, and the vapors of iodine and bromine. Oxygen gas, on the contrary, is highly magnetic—the most so of all the gases. A heated gas is diamagnetic to the same when cold. The brightest flames are the most strongly diamagnetic.

We close this article upon electricity in the words of Professor Faraday: "How rapidly the knowledge of molecular forces grows upon us, and how strikingly every investigation tends to develop more and more their importance, and their extreme attraction as an object of study. A few years ago, magnetism was to us an occult power, affecting only a few bodies; now it is found to influence all bodies, and to possess the most intimate relations with electricity, heat, chemical action, light, crystallisation, and through it, with the forces concerned in cohesion; and we may, in the present state of things, feel well urged to continue in our labors, encouraged by the hope of bringing it into a bond of union with gravity itself."

INORGANIC CHEMISTRY PROPER.

INTRODUCTORY.

THE world in which we live is formed, in its different parts, of a number of distinct kinds of matter, amounting, according to the present state of our knowledge, to about 55. These are called elements, elementary bodies, or simple substances.

The forms of matter with which we are most familiar, however, are not elementary. If we examine the matter of which a rock, a tree, an animal, the atmosphere, or the ocean is respectively composed, we shall find that all those objects may be proved to contain two or more distinct kinds of matter; that is, two or more elements. Where this is the case, we call the substance a compound body.

A compound, therefore, may be resolved into its elements; whereas an element, or simple substance, cannot be made, by any means yet known to us, to yield more than one kind of matter. Brass, which is compound, may be resolved into copper and zinc; but from copper or zinc, we can obtain only copper or zinc. Vermilion may be shown to contain sulphur and mercury; but sulphur can only be made to yield sulphur, and mercury, mercury.

But when we call any substance elementary, or simple, we do not mean that it is certainly or essentially so; we only say that hitherto, in our hands, and exposed to all the various agencies which we can bring to bear on it, it has yielded only one kind of matter, or element, and no more. In the early part of the present century, the alkalies and earths were believed to be elementary bodies, because only one kind of matter had ever been obtained from them: but the new power of galvanism enabled Davy to discover that all these bodies were compound. It is far from being improbable that, in the progress of discovery, several, perhaps many, of the 55 elements which we are now compelled to admit, may, in like manner, prove to be really compound bodies.

Till then, however, we must be content to class together, as elements, all those bodies which have not yet been resolved into other kinds of matter; and of these undecomposed bodies, or

elements, all material objects are constituted. Here follows the list of the elementary bodies at present admitted, with the abbreviation, or symbol, which is used for each element placed after the name :—

ELEMENTS.

Oxygen	O	Manganese	Mn
Hydrogen	H	Iron (Ferrum)	Fe
Nitrogen	N	Cobalt	Co
Sulphur	S	Nickel	Ni
Phosphorus	P	Zinc	Zn
Carbon	C	Cadmium	Cd
Chlorine	Cl	Lead (Plumbum)	Pb
Bromine	Br	Tin (Stannum)	Sn
Iodine	I	Bismuth	Bi
Fluorine	F	Copper (Cuprum)	Cu
Boron	B	Uranium	U
Silicon	Si	Mercury (Hydrargyrum)	Hg
		Silver (Argentum)	Ag
Selenium	Se	Palladium	Pd
		Rhodium	R
Potassium (Kalium)	K	Ruthenium ?	
Sodium (Natrium)	Na	Iridium	Ir
Lithium	L	Platinum	Pt
Barium	Ba	Gold (Aurum)	Au
Strontium	Sr	Osmium	Os
Calcium	Ca	Titanium	Ti
Magnesium	Mg	Columbium (Tantalum)	Ta
Aluminum	Al	Pelopium ?	
Glucinum	G	Niobium ?	
Yttrium	Y	Tellurium	Te
Zirconium	Z	Tungsten (Wolfram)	W
Thorium	Th	Molybdenum	Mo
Cerium	Ce	Vanadium	V
Lanthanium	La	Chromium	Cr
Didymium ?		Antimony (Stibium)	Sb
Erbium ?		Arsenic	As
Terbium ?			

(The symbols or abbreviations are in every case taken from the Latin names of the elements, so as to be universally understood. Should the existence of the new metals, discovered by Mosander, viz: Didymium, Erbium, and Terbium, as well as of those announced by Rose, viz: Pelopium and Niobium; and of the metal Ruthenium, found by Klaus in the ore of Platinum, be established, the number of the elements will be 61.)

Of the above list of elements, about 14 constitute the great mass of our earth and of its atmosphere. The remainder occur only in small quantity, comparatively; while nearly a third of the whole number is so rare, as not to admit of any useful application.

By their external aspect, the elements may be divided into two classes; and these classes are also found to possess other

distinctive characters. Thus the twelve first in the list, which are called non-metallic bodies, or metalloids, are easily distinguished from all those after potassium, inclusive, which are metals. The latter possess that peculiar brightness and opacity of surface which is called the metallic lustre, of which the former are destitute. Again, the metals are all found to be excellent conductors of heat and electricity, while the metalloids conduct these influences very badly, with the exception of charcoal, which, when in certain states, conducts electricity almost like a metal.

Selenium has the metallic lustre, and is by some considered a metal; but it is a non-conductor of heat and electricity, and in all its chemical relations and analogies belongs to the non-metallic bodies.

This division of the elements is of great use in facilitating the study of chemistry.

The elements are capable of combining together, metalloids with metalloids, metals with metals, and metalloids with metals.

When two elements unite together, they give rise to a new substance, a compound of the two; and, generally speaking, the compound has properties entirely distinct from those of its elements. Thus, sulphur and mercury, a yellow earthy solid and a white fluid metal, unite, and give rise to a fine red powder which is vermilion. It is not possible, by the eye, to distinguish two kinds of matter in the vermilion, any more than in its elements, so completely have the properties of those elements disappeared. But, by chemical means, we can prove that vermilion contains both mercury and sulphur. These elements are said to be combined, so as to produce vermilion, which is said to be a compound, or to be composed of them. In such a case, the combined elements can no longer be separated mechanically from each other. They are held together by a force which is called chemical attraction, or *affinity*, the real nature of which we do not know. It resembles cohesion, since it holds together the particles of matter: but while cohesion is only exerted between particles of the same nature, as, for example, between those of sulphur, or between those of vermilion, affinity is only exerted between particles of different kinds of matter, for example, between the particles of sulphur and of mercury.

By affinity, then, we understand simply that force, whatever may be its nature, by which the particles of one elementary body are made to unite with those of another. When once united, the particles of the compound obey the laws of cohesion exactly as if they were simple particles.

It is the object of chemistry to investigate the properties of the elements, the laws which regulate their mutual actions, and the nature and properties of the compounds which arise from their union.

Before describing the individual elements, it is necessary to explain to the reader certain terms and phrases of very frequent occurrence, as well as to mention the general laws which regulate chemical combination.

Combination occurs when two or more bodies unite together; *decomposition* takes place when bodies, previously united, are made to separate from each other.

When oxygen enters into combination with any other element, the compound is called an *oxide*; the compound of chlorine with any other element is called a *chloride*; and with bromine, iodine, and fluorine, we have, in the same way, bromides, iodides, and fluorides. The compounds of sulphur, phosphorus, carbon, selenium, &c., with metals, are called *sulphides*, *phosphides*, *carbides*, *seleniurides*, &c.

When a compound body possesses a sour taste, reddens vegetable blue colors, and neutralizes alkalies, it is called an *acid*. If composed of oxygen united to a metalloid, such as carbon, or a metal, such as chromium, the acid is simply named from the metalloid or metal, as carbonic acid, chromic acid. But if the acid contains hydrogen united to a metalloid, the word "hydro" is prefixed; as hydro-chloric acid (hydrogen and chlorine), hydro-sulphuric acid (hydrogen and sulphur), &c.

Where the same element forms with oxygen several acids, they are distinguished by their terminations, as sulphuric acid, sulphurous acid: the acid in it always containing most oxygen: but where new acids of intermediate composition are discovered, it is necessary to use the prefix "hypo," — as hypo-sulphurous acid, hypo-sulphuric acid, meaning acids containing less oxygen than sulphurous or sulphuric acids respectively; or "hyper," as hyper-chloric acid, meaning an acid containing more oxygen than chloric acid.

When a compound body has an acrid, urinous taste, restores to blue the color reddened by an acid, and, above all, if it possess the property of neutralizing acids, or causing their acid properties to disappear, it is called an *alkali*, or more generally a *base*, or a *basic substance*.

We have seen that oxygen is an element of many acids; it is also an element in most bases. Almost all the metals are capable of forming one base, several form more than one base, with oxygen. These bases are usually called *oxides* of the metal; and where there are two, that which contains least oxygen is usually called *protoxide*, and that which contains most oxygen, *peroxide*; as the protoxide and peroxide of iron, &c.

Acids and bases unite together, and the characteristic properties of both disappear. They are said mutually to *neutralize* each other, and the resulting compound is called a *salt*. If neither the acid nor base be in excess, the salt is a *neutral salt*; if the acid predominate, it is called an *acid salt*, or a *super salt*; and if the

base prevail, it is called a basic salt or a sub-salt. The salt is named from both the ingredients. Thus, when sulphuric acid neutralizes soda, the resulting salt is called the sulphate of soda; when phosphoric acid unites with lime, the acid being in excess, the salt is called acid phosphate of lime, or superphosphate of lime; and when nitric acid unites with oxide of mercury, the latter being in excess, the compound is called basic nitrate of mercury, or subnitrate of mercury.

Besides acids and bases, there is a third kind of oxides, namely, such as have neither acid nor basic properties. They are called indifferent oxides, and sometimes superoxides; as for example, peroxide, properly superoxide of manganese.

The term "radical" is applied to any body which, by uniting with an element, can give rise to an acid or a base. Most of the elements play the part of radicals: but we have, besides, compound radicals, containing two elements, like cyanogen, or even three or more elements, like benzoyle or cacodyle. The compound radicals unite with elements, just as if they were themselves elementary. Thus, cyanogen unites with hydrogen to form an acid, and cacodyle unites with oxygen to form a base.

COMBINATION.

THE force of chemical attraction, or affinity, is unequal in the case of different substances. Thus, the affinity between potassium and oxygen is more powerful than that between gold and oxygen.

The capacity of one body to unite with another is mainly effected by two circumstances; namely, the state or form of the substances in question, whether solid, liquid, or gaseous, and the temperature at which they are brought together.

Cohesion tends to keep the particles of bodies in close proximity, while the tendency of heat is to separate them from each other. When cohesion predominates over the repulsion due to heat, the body is solid: when cohesion and repulsion are exactly balanced, it is liquid; and when repulsion predominates, it becomes gaseous.

It is obvious that, since chemical attraction operates between the particles of different bodies, and only when they are at infinitely small distances, the cohesion between the particles of two solid bodies respectively must impede chemical action by preventing the sufficiently close approximation and intermixture of the particles which have affinity for each other. Hence the solid form is most unfavorable to chemical action, although, in rare cases, the power of affinity is sufficient to overcome the obstacle. Thus, phosphorus and iodine, both in the solid form, act powerfully on one another.

But if one or both of the bodies be liquid, the particles of both readily come so near as to admit of affinity producing its full effect. Thus, bromine acts violently on phosphorus, although the latter is solid ; nitric acid, in like manner, dissolves metals, and the same acid acts with great energy on alcohol. Indeed, the liquid form is so favorable to chemical action, that the chemist generally endeavors to have one or both of the substances, whose action he wishes to try, in that form.

Moreover, when two solid bodies, as is generally the case, refuse to act on each other, it is commonly sufficient to cause one of them to assume the liquid form. This may be done in two ways ; either by applying a sufficient heat to melt it, or by dissolving it in water or some other solvent. Thus iron and sulphur, when mixed in the solid form, do not combine ; but if the sulphur be melted by heat, rapid combination takes place. Again : citric acid and carbonate of soda do not act on each other when dry ; but if water be added to the mixture, the acid dissolves, and brisk action ensues.

It is evident that heat, being opposed to cohesion, will promote chemical action whenever cohesion or the solid form is the obstacle : and this is the source of the immense value of heat in chemical and manufacturing processes ; as, for example, in the smelting of metals from their ores.

But when cohesion has been still further overcome, and the body has assumed the gaseous form, a new impediment is offered to chemical action. The particles, by the predominance of the repulsion due to heat, are now so far removed from each other, as not to come readily within the sphere of chemical affinity. Hence, two bodies in the gaseous form seldom act on one another, unless their mutual attraction be very strong, as in the case of hydrochloric acid gas and ammoniacal gas ; or by the aid of heat, light, or electricity, as in the case of chlorine and hydrogen gases. As heat is here the cause of the obstacle, the appropriate remedies are cold and compression, which tend to bring the particles nearer. Heat and electricity are supposed to act by producing compression of some particles in consequence of the expansion of others ; but heat certainly acts also by increasing the force of affinity.

Even where only one of the bodies is gaseous, chemical action is much impeded, especially if the other be solid. Still, in many cases, solids and liquids do slowly act on gases : and by such means some of the most important processes in the organic kingdoms are carried on ; as, for example, the respiration of animals, and the growth and decay of plants.

In some cases, as in that of hydrochloric acid gas, the affinity between the gas and water is so powerful, that they combine instantaneously when brought into contact.

There are other cases in which solid bodies at the ordinary temperature are incapable of combining with gases, but in which

a high temperature, although it opposes chemical action by its tendency to remove still further the particles of the gas, yet, on the other hand, so much exalts the power of affinity as to be the most powerful promoter of combination. The effect of heat in causing wood, coal, or charcoal, to combine with oxygen, as in ordinary combustion, is a familiar example of this; and as, in this form of experiment, the combustion, once begun, produces a great amount of heat without external aid, it is in this manner that heat is obtained and rendered available for the useful purposes above alluded to.

A gaseous body, which under ordinary circumstances will not combine with another substance, may be made to do so, if presented to it in the nascent state, that is, while it is separating from another solid or liquid body. Thus hydrogen gas, if formed in contact with sulphur, will not combine with it; but if the hydrogen be formed by the action of an acid on sulphide of iron, the sulphur is presented to the gas at the very moment at which the former is separating from the iron, (in the nascent state, as it is called,) and the gas which is now disengaged is a compound of sulphur and of hydrogen.

It sometimes happens that the combination of two bodies is promoted by the presence of a third, which does not combine with either of the two, nor even with the resulting compound. Thus, if oxygen and hydrogen gases be mixed, they do not combine; but the contact of spongy platinum causes their immediate union, although the metal combines neither with oxygen nor with hydrogen, nor with water, the product of their combination.

But in all cases where the third body has a powerful affinity for the resulting compound, its effect in promoting combination is very great, and has got the name of predisposing affinity. Thus, zinc does not decompose water; but if sulphuric acid be added, the water is decomposed, its oxygen uniting with the zinc. In this case, according to the usual explanation, the oxide of zinc formed unites with the acid, and the affinity of the acid for the oxide of zinc is called a predisposing affinity, as if the acid had caused the formation of oxide of zinc because of its affinity for that oxide when formed. In truth, however, all the changes that occur are strictly simultaneous, and the phrase "predisposing affinity," is not an accurate one. It is, however, sufficiently convenient and expressive to be a good deal used in regard to similar cases.

When two bodies, A and B, are in combination, the force with which they are actually held together is not dependent alone on their mutual affinity, but also on their relative mass. In the compound ABB, A is retained by a greater force than in AB. This is the result of the increased mass of B. Or we may view it thus: In the compound AABB, the first A may be moved with compara-

tive facility, the relative masses of A and B being equal. But after the removal of the first A, the mass of B is relatively doubled, and the second A requires for its removal a much greater force. It is obvious that, conversely, in ABB, the second B is less forcibly retained than the B in AB.

When a body, A, is presented to two bodies, B and C, for each of which it has affinity, although unequal, then, if nothing interfere, A will divide itself between B and C, according to its affinity for each. But the effect of mass is seen here also; for if the mass of C, the body for which A has least affinity, be much larger than that of B, then the division will be no longer in the ratio of the affinities to A, but C will obtain more, and B less of A.

When to a compound body, AB, another body, C, is added, having an affinity for B, both combination and decomposition occur: for AB is decomposed, and at the same time B, which separates from A, enters into combination with C. It does not often happen that the mere force of affinity is sufficient to complete such a change, but such cases do occur; as where iron acts on a salt of copper, or copper on a salt of silver, the one metal taking the place of the other, and the latter being entirely separated.

More frequently a part only of B is separated from A and combines with C; and thus there are present, at the same time, the compounds AB and BC, while part of A and of C exists in the free or uncombined state along with them.

If now the free A be removed from the mixture, the free C, being unresisted, at last effects a complete separation of A. The removal of the free A is effected either when that body assumes the solid form by virtue of its great cohesion, or when it takes the form of gas in consequence of its feeble cohesive power, or of the application of heat. The precipitation of an insoluble oxide by a soluble alkali is an example of the former; the formation of glass by the fusion of silicic acid with carbonate of potash is an illustration of the latter case. Similar cases are of constant occurrence.

In both cases, the decomposition is the more easy and complete, the larger the mass of the decomposing body C employed. And from this follows the curious fact, that if, in any given temperature, we can alter the form or the mass of either of the bodies which act on one another, the result of the experiment is likewise altered: nay, it may actually be reversed. Thus, if oxide of iron be exposed at a red-heat to a current of hydrogen gas, the oxide is decomposed, its oxygen, with the hydrogen, forming water, while the iron is reduced to the metallic state. But if now the iron be heated red-hot, and exposed to a current of the vapor of water, the water is decomposed, its oxygen, with the iron, forming oxide of iron; while the hydrogen is reduced to the free state.

Decomposition is rendered complete, not only when the body A, which is separated, assumes the solid form, but also when A

remains liquid or dissolved, and the new body, BC, takes the solid form, or is insoluble. Hence the nature of the liquid, in which a chemical action goes on, exerts a most important influence on the result of the action.

When two compound bodies, AB and CD, act on one another, both decomposition and combination occur. When complete, the change is called double decomposition, since both AB and CD are decomposed; but at the same time the two new combinations, AD and CB have been formed. Should the change be only partial, the four compounds AB, CD, AD, and CB, will be present together. Double decomposition is of very frequent occurrence.

In cases where a compound, AB, cannot be decomposed by a body, C, even with the aid of a high temperature, the addition of a fourth body, D, if it have an affinity for A, while there is an affinity between C and B, will often enable us to accomplish the decomposition. Thus, oxide of aluminum cannot be decomposed by charcoal even at a white-heat: but when a current of chlorine gas is passed over the mixture, the chlorine, by virtue of its affinity for aluminum, added to that of carbon for oxygen, effects the decomposition, and we obtain chloride of aluminum and oxide of carbon.

When a compound of three or more elements is exposed to a high temperature, the elements unite to form such new compounds as are not decomposable by the temperature employed.

If such a compound be heated along with a body which is capable of forming with some of the elements in certain proportions a more fixed compound, the remaining elements give rise to one or more new and more volatile compounds.

The two last are the principal laws which regulate the phenomena of the destructive distillation of organic substances.

Such are the most important facts in regard to the circumstances under which combination and decomposition occur. We now come to the subject of the proportions in which bodies combine together, or

COMBINATION IN DEFINITE PROPORTIONS.

The experience of chemists, derived from many thousand analyses, has established the following laws; which, however, are purely the expression of ascertained facts, and involve no hypothesis whatever:—

1. The quantity, by weight, of the body B, which is taken up by a given weight of the body A, to produce the compound AB, is definite and unchangeable. Thus 8 grains of oxygen are invariably taken up by 1 grain of hydrogen (in round numbers) to produce water: or, in other words, 9 grains of water are invariably composed of 8 grains of oxygen and 1 of hydrogen.

2. When a body A combines with a body B in more proportions than one, producing more than one distinct compound, the quantity, by weight, of B, which is united to the same weight of

A in the different compounds, increases according to one of two ratios. According to one, the series of compounds formed is—

A + B,	1st compound	. . .	B = 1
A + BB,	2nd do.	. . .	B = 2
A + BBB,	3rd do.	. . .	B = 3
A + BBBB,	4th do.	. . .	B = 4
A + BBBBB,	5th do.	. . .	B = 5

According to the other, the series of compounds is—

A + BBB,	1st compound,	. . .	A : B = 1 : 3
A + BBBBB,	2nd do.	. . .	A : B = 1 : 5
A + BBBBBB,	3rd do.	. . .	A : B = 1 : 7

The compounds of nitrogen and oxygen offer an example of the first series of multiple proportions. In the first of these compounds,

	14	grs. of nitrogen	are united with	8	of oxygen.
In the 2nd.	14	"	"	16	"
" 3rd.	14	"	"	24	"
" 4th.	14	"	"	32	"
" 5th.	14	"	"	40	"

The compounds of arsenic and oxygen will illustrate the second series. In the first of these compounds,

	75.4	grs. of arsenic	are united with	24	of oxygen.
In the 2nd.	75.4	"	"	40	"

Here the quantities of oxygen increase in the ratio of 3 to 5.

3. The proportions, by weight, in which bodies combine, are proportional to each other. That is, if a given weight of A unite with weights of B and C, which are to each other as 3 to 4, for example, then if a fourth body, D, unite with B and with C also, the weights of B and C combined with D will likewise be to each other as 3 to 4.

Thus, 100 grs. of potassium unite with 20.41 grs. of oxygen; 100 grs. of potassium unite also with 41.06 grs. of sulphur. Now 100 grs. of silver unite with 7.39 grs. of oxygen, and also with 14.88 grs. of sulphur. According to this law, we find that $7.39 : 14.88 :: 20.41 : 41.06$; or, in other words, that the weights of oxygen and sulphur which unite with 100 grs. of silver bear to each other the same proportion as the weights of those elements which combine with 100 grs. of potassium.

Another consequence of this law is, that the weights of two bodies which combine with the same weight of a third body, will also represent the weights of these two bodies which unite together, if they are capable of combination; or if the proportions should not be precisely the same, they will be found to be multiples or submultiples of those weights.

Thus, 8 grains of oxygen combine with 1 grain of hydrogen to form water; and 8 grains of oxygen combine with 16 of sulphur to form hyposulphurous acid. Now, sulphur and hydrogen combine together to form hydrosulphuric acid; and that compound is found to contain sulphur and hydrogen in the proportion of 16 grs.

of the former to 1 gr. of the latter. The same elements form another compound, the persulphide of hydrogen; and in this the proportions are 32 of sulphur to 1 of hydrogen. Now $32 = 16 \times 2$.

If, therefore, we know the weights of two bodies, B and C, which combine with a given weight of A, we also know the relative weights in which, or in multiples or submultiples of which, B and C will combine together.

Now oxygen is capable of uniting with all the other elements, (save perhaps with fluorine); and therefore if we ascertain by experiment the weights of the different elements which combine with a given weight of oxygen, the weights thus obtained will inform us, not only in what proportions (or their multiples) these elements combine with oxygen, but also in what proportions (or their multiples) they combine with each other, provided they are capable of doing so.

It is obviously of no importance what number we select to represent the standard weight of oxygen, to which the other elements are referred. On the Continent 100 is usually taken, and the combining numbers of the other elements are referred to oxygen as 100. In this country, for the sake of convenience in calculation, advantage has been taken of the fact that the combining weight or number of hydrogen is the smallest of all, and hydrogen has consequently been made the standard, with the number 1. Now as 1 of hydrogen is found to combine (in water) with 8 of oxygen, it is obvious that if hydrogen be represented by 1, oxygen will be represented by 8. Again, on the Continental scale, oxygen being 100, hydrogen must be $\frac{1}{8} = 12.5$, the proportion being preserved exactly the same. So that it is equally correct to say that water is composed of 100 grs. of oxygen, combined with 12.5 of hydrogen, and to say that water consists of 8 grs. of oxygen and 1 of hydrogen. Both scales are so extensively employed, that the chemist ought to be familiar with both, and accordingly, both are subjoined. It is hardly necessary to point out that the numbers of the scale in which oxygen = 100, which we shall call the oxygen scale, may be easily reduced to those of the other, or hydrogen scale, in which oxygen = 8 by dividing the former by 12.5; and that conversely the numbers of the hydrogen scale, if multiplied by 12.5, are converted into those of the oxygen scale.

The numbers, then, attached to the names of the elements in the subjoined Table, are the results of experience, and merely represent the relative weights of the elements which (or multiples of them) combine with 100 of oxygen on the one scale, and with 8 of oxygen on the other. In this work we shall use the numbers of the hydrogen scale: but the table of the other scale will be of use to those who read foreign chemical works; and the numbers of one scale may at any time be substituted for those of the other, provided we do not mix them up together.

TABLE OF COMBINING PROPORTIONS.

Elements.	Symbol.	Oxygen. = 100.	Hydrogen. = 1.	Elements.	Symbol.	Oxygen. = 100.	Hydrogen = 1.
Aluminium . . .	Al	171.17	13.72	Mercury (Hydragyrum) . . .	Hg	2531.65	202.87
Antimony (Stibium) . . .	Sb	806.45	129.24	Molybdenum . . .	Mo	598.52	47.96
Arsenic . . .	As	470.04	37.67	Nickel . . .	Ni	369.68	29.62
Barium . . .	Ba	856.88	68.66	Nitrogen . . .	N	177.04	14.19
Bismuth . . .	Bi	886.92	71.07	Osmium . . .	Os	1244.49	99.72
Boron . . .	B	136.25	10.81	Oxygen . . .	O	100.00	8.013
Bromine . . .	Br	978.30	78.39	Palladium . . .	Pd	665.90	53.36
Cadmium . . .	Cd	636.77	55.83	Phosphorus . . .	P	196.14	31.44
Calcium . . .	Ca	256.02	20.52	Platinum . . .	Pt	1233.50	98.84
Carbon . . .	C	75.40	6.04	Potassium (Kalium) . . .	K	489.92	39.26
Cerium . . .	Ce	574.7	46.05	Rhodium . . .	R	651.39	52.20
Chlorine . . .	Cl	442.65	35.47	Selenium . . .	Se	494.58	39.63
Chromium . . .	Cr	351.82	28.19	Silicon . . .	Si	277.31	22.92
Cobalt . . .	Co	368.99	28.57	Silver (Argentum) . . .	Ag	1351.61	108.31
Columbium (Tantalum) . . .	Ta	2307.44	184.90	Sodium (Natrium) . . .	Na	290.90	23.31
Copper (Cuprum) . . .	Cu	395.7	31.71	Strontium . . .	Sr	547.29	43.85
Fluorine . . .	F	223.80	18.74	Sulphur . . .	S	901.17	32.94
Glucinum . . .	G	331.26	26.54	Tellurium . . .	Te	801.76	64.25
Gold (Aurum) . . .	Au	9486.02	199.2	Thorium . . .	Th	744.90	59.831
Hydrogen . . .	H	19.479	1.00	Tin (Stannum) . . .	Sn	735.29	58.92
Iodine . . .	I	1579.50	126.57	Titanium . . .	Ti	303.66	24.33
Iridium . . .	Ir	1253.50	98.84	Tungsten (Wolfram) . . .	W	1246.25	99.70
Iron (Ferrum) . . .	Fe	339.21	27.18	Vanadium . . .	V	856.86	68.66
Lead (Plumbum) . . .	Pb	1294.50	103.73	Yttrium . . .	Y	2711.36	217.2
Lithium . . .	Li	80.33	6.44	Zinc . . .	Zn	402.51	32.25
Magnesium . . .	Mg	156.35	12.89	Zirconium . . .	Zr	403.23	39.31
Manganese . . .	Mn	345.89	27.72			490.20	33.67

The number 39, attached to potassium,* expresses the fact that 39 grains of potassium combine with 8 of oxygen, and 16 of sulphur; 8 and 16 being the numbers respectively attached to oxygen and sulphur.

These numbers further express the facts, that if we wish to convert 47 grains of oxide of potassium, composed of 39 of potas-

* Here the fractions, for convenience, are omitted.

sium and 8 of oxygen, into sulphide of potassium, 16 grs. of sulphur will be required to displace the 8 of oxygen, and will give 55 grains of sulphide.

We thus perceive that 16 grains of sulphur are the equivalent of 8 grains of oxygen. Hence the term "equivalent" is used as synonymous with combining proportion, and we shall in this work employ the term equivalent by preference.

When an element combines with oxygen in only one proportion, the equivalent of that element is the weight which combines with 8 (or on the other scale with 100) of oxygen. Or we may calculate the equivalent from the compound, if there be one, of the element with chlorine.

Thus, in the oxide of potassium (potash), 39 grs. of potassium are combined with 8 of oxygen. If there were no other compound of potassium and oxygen, we should take 39 for the equivalent of potassium. But there is another compound of these elements, and in order to acquire certainty, we refer to the compound (there is but one) which potassium forms with chlorine. We find this to contain 39 grs. of potassium, with 35 of chlorine; and as 35 is the equivalent of chlorine, we conclude that 39 is the true equivalent of potassium.

Where an element combines with oxygen in several proportions, we are more uncertain. If the proportions of oxygen belong to the series of simple multiples, the equivalent is usually calculated from that compound which contains least oxygen, assuming that to contain an equivalent of oxygen.

Thus nitrogen forms 5 compounds with oxygen. In the first, 14 grs. of nitrogen are combined with 8 of oxygen; in the fifth, 14 grs. of nitrogen are united with 40 of oxygen. Taking the former, we conclude 14 to be the equivalent of nitrogen; but if we selected the other, then the equivalent of nitrogen would necessarily be five times smaller. On the ordinary view, we consider the fifth compound to consist of one equivalent of nitrogen = 14, and 5 equivalents of oxygen = $8 \times 5 = 40$. But it will be seen that this is, to some extent, arbitrary; and that we might consider the fifth compound as formed of one equivalent of each, and the first as composed of one equivalent of oxygen, and 5 of nitrogen.

The usual system of equivalents above explained being consistent and uniform, as far as possible, is very convenient; but the student must remember, that while the combining proportions are fixed, it is, in any one compound, a matter of arbitrary choice, whether it be viewed as containing one or more equivalents of any element.

A very large proportion of elements, however, combine among each other according to laws so simple, that when we have assumed 8, for example, to represent one equivalent of oxygen, we need have no doubt as to the equivalents of the other elements.

In those compounds of one element with two or three proportions of another, where the quantities of the latter are not simple

multiples, but belong to the series 3 : 5 : 7, much greater uncertainty prevails as to the equivalents. Thus, arsenic, antimony, and phosphorus, form compounds with oxygen, chlorine, and sulphur, belonging to this latter series; and chemists are not fully agreed whether they ought to consider the quantity of arsenic, antimony, or phosphorus, which combines with three or five equivalents of oxygen, chlorine, and sulphur, as representing one equivalent, or two equivalents. The same doubt occurs in other cases: and we are guided, in such instances, chiefly by probabilities, and by the rule to avoid, as much as possible, fractions of equivalents. Thus, if we suppose the first oxide of arsenic to contain 1 equivalent of arsenic, and 1 of oxygen, the second must contain 1 equivalent of arsenic, and $1\frac{1}{2}$ equivalents of oxygen. We, therefore, prefer to consider the first as formed of 2 eq. arsenic, and 3 eq. oxygen; and the second as formed of 2 eq. arsenic, and 5 eq. oxygen. There is still a third way by which also fractions may be avoided; and that is, to make the first a compound of 1 eq. arsenic, and 3 eq. oxygen; and the second a compound of 1 eq. arsenic, and 5 eq. oxygen. This last view, however, does not in many cases agree so well as the preceding, with the composition of the other compounds of the same element.

It is to be observed, that whichever view is adopted, the facts of the proportions remain unchanged. It is only the equivalent of arsenic which requires to be altered.*

The equivalent of a compound body is the sum of the equivalents of its component parts. Thus, potash being composed of 1 eq. of potassium, 39, and 1 eq. of oxygen, 8, its equivalent is $39 + 8 = 47$. Sulphuric acid is composed of 1 eq. of sulphur, 16, and 3 eq. of oxygen, 24; and, consequently, its equivalent is $40 = 16 + 24$. As in the case of elementary bodies, the equivalents represent the combining proportions. Thus, the neutral sulphate of potash contains 47 grains of potash, and 40 grains of sulphuric acid. The law of multiples also applies to compound bodies; for there is another compound of sulphuric acid and potash, the bisulphate of potash, in which 47 grs. of potash are combined with 80 grs. of sulphuric acid, or 1 eq. of potash with 2 eq. of the acid.

The use of equivalents enables us to define more accurately some of the more important classes of compounds.

Oxygen acids are compounds of one or two equivalents of the metalloids, and of certain metals, with two or more equivalents of oxygen.

Oxygen bases are, without exception, compounds of metals with oxygen. In most cases, the base contains 1 eq. of the metal, and 1 eq. of oxygen; in a few bases there are two eq. of the

* Since the above was written, chemists have pretty generally agreed to double the equivalents of phosphorus, antimony, sulphur and arsenic. 8.

metal, and 3 eq. of oxygen; and in one or two there are 2 eq. of metal to 1 eq. of oxygen.

A neutral salt is a compound of 1 eq. of an oxygen acid, with 1 eq. of a base; or a compound of 1 eq. of a metal with 1 eq. of the radical of a hydrogen acid. Thus neutral sulphate of potash contains 1 eq. of sulphuric acid, and 1 eq. of potash; while common salt is composed of 1 eq. of sodium, and 1 eq. of chlorine.

A hydrogen acid is, in almost every case, composed of 1 eq. of hydrogen, and 1 eq. of a radical simple or compound. Thus hydrochloric acid is composed of 1 eq. of hydrogen, and 1 eq. of chlorine; and hydrocyanic acid is formed of 1 eq. of hydrogen, and 1 eq. of the compound radical cyanogen.

The equivalent of an acid is that quantity which will form a neutral salt with one equivalent of a base; and, in like manner, the equivalent of a base is that quantity which forms a neutral salt with one equivalent of an acid.

The equivalent of potash is 47. Now, in order to form a neutral salt with 47 grs. of potash, 54 grains of nitric acid must be added: 54 is, therefore, the equivalent of nitric acid. Again, 40 is the equivalent of sulphuric acid, and in order to form a neutral salt with 40 grs. of sulphuric acid, 31 grs. of soda are required. Hence, 31 is the equivalent of the base, soda or oxide of sodium.

Since the equivalent of a compound body is the sum of the equivalent of its constituents, it follows, that if we know the equivalent of a compound, and the relative proportions by weight of its component parts, we can calculate the *number* of equivalents of each element contained in the compound. For example, we find by analysis, that 100 grs. of hyposulphuric acid are composed of 44.59 grs. sulphur, and 55.41 grs. oxygen. We also find, by experiment, that the equivalent of hyposulphuric acid is 72. Now, in order to ascertain the number of equivalents of sulphur and oxygen contained in the acid, we first examine how much sulphur and oxygen are present in 72 grs. of the acid. It is clear that if 100 grs. contain 44.59 of sulphur, 72 will contain 32 of sulphur; and the remainder, 40, must be oxygen. But 32 is equal to 2 eq. of sulphur, the equivalent of sulphur being 16; and 40 is equal to 5 equivalents of oxygen, or 5 times 8. Hence the acid in question is composed of 2 eq. of sulphur, combined with 5 eq. of oxygen.

The rule for the above calculation is to ascertain the proportions of the elements in the equivalent number of the compound; and as these proportions represent respectively the sums of the equivalents of the elements, to divide the numbers by the equivalents. In the above case, 32 (the proportion of sulphur in 72, the equivalent of the acid) $\div 16 = 2$ eq. of sulphur; and 40 (the proportion of oxygen in 72 of the acid) $\div 8 = 5$ eq. of oxygen.

In cases where we have ascertained the proportions of the elements in a compound, but are ignorant of its equivalent or combining proportion, we cannot determine with certainty the absolute, but only the relative number of equivalents contained in the compound. For example, it is shown that 100 grs. of sugar of milk contain —

Carbon	40.45
Hydrogen	6.61
Oxygen	52.94

100.00

But as sugar of milk enters into hardly any combinations, we cannot ascertain its combining proportion or equivalent, and thus it is, of course, impossible to tell how many equivalents of carbon, hydrogen, and oxygen, are contained in 1 eq. of sugar of milk. But we can ascertain the relative numbers of equivalents as follows. Divide the weight of carbon in 100 parts of sugar of milk, by the equivalent of carbon, which is $6 : 40.45 \div 6 = 6.74$. Next, divide the weight of hydrogen in 100, which is 6.61, by the equivalent of hydrogen, which is $1 : 6.61 \div 1 = 6.61$. Lastly, divide 52.94 , the weight of oxygen in 100, by 8, the equivalent of oxygen. $52.94 \div 8 = 6.61$. Here, then, the relative numbers of equivalents of carbon, hydrogen, and oxygen, are represented by the numbers 6.74, 6.61, and 6.61 : or, making allowance for the unavoidable errors of manipulation, there is an equal number of equivalents of each. We cannot say whether sugar of milk contains 1, 2, 3, 4, 6, 12, or any other number of equivalents of each of its elements; we only know that if 1 eq. of sugar of milk contains 6 eq. of carbon, it must likewise contain 6 of oxygen and 6 of hydrogen.

When a body, A, combines with B and C, and the number of equivalents of B and of C, which respectively unite with 1 or more equivalents of A is equal, the compounds A B and A C are said to correspond in constitution, or they are called corresponding compounds. Thus 1 eq. of potassium combines with 1 eq. of oxygen, and 1 eq. of potassium combines with 1 eq. of chlorine, and we say that chloride of potassium and protoxide of potassium (potash) are the corresponding chlorine and oxygen compounds of that metal.

When two compounds, A B and C D, respectively consist of an equal number of equivalents, they are said to be proportional compounds. Thus, oxide of potassium contains 1 eq. of oxygen, and 1 eq. of potassium; hydrochloric acid contains 1 eq. of hydrogen and 1 eq. of chlorine; and we say that the composition of hydrochloric acid, is proportional to that of oxide of potassium (potash).

When two proportional compounds mutually decompose each other, the resulting compounds are likewise proportional; and we

have a complete case of double decomposition. Thus 1 eq. hydrochloric acid and 1 eq. oxide of potassium, act on each other, and give rise to water (1 eq. oxygen and 1 eq. hydrogen) and to chloride of potassium (1 eq. chlorine and 1 eq. potassium), which new compounds are obviously proportional. Any excess of either of the original compounds, beyond the 1 eq. required, remains undecomposed, and mixes with the new compounds.

When two bodies act on one another, which are not proportional, they may do so in the proportion of 1 eq. of each, or in the proportion of 1 eq. of the one compound to 2 or more of the other.

In the former case there may be formed —

1. Two new compounds, not proportional to each other, but corresponding respectively to the two original compounds, or—
2. Two new proportional compounds, in which case one of the elements of one of the original compounds must be partially separated.

We may thus have —

1. $A B + C D D$ producing $A C + B D D$; or,
2. $A B + C D D$ producing $A C + B D + D$.

In the latter case there may be formed —

1. An equal number of new compounds, not proportional, but corresponding to the original compounds.
2. Two new compounds, proportional to each other, in which case an element has been partially separated.
3. Two new compounds, not proportional, and one of which does not even correspond to either of the original compounds. Here also an element has been partially separated.

We may thus have —

1. $A + 5 B$ and $5 C D$ producing $A + 5 C$ and $5 B D$.
2. $A + 2 B$ and $2 C D$ producing $A C$, $2 B D$, and C .
3. $A + 5 B$ and $5 C D$ producing $A + 3 C$, $5 B D$, and $2 C$.

Numerous examples of these and of many similar modes of decomposition will occur in the course of this work. For the present, our space makes it necessary to confine ourselves to the general statements.

Under all circumstances, and in the most complicated chemical changes, the composition of the new products must admit, when expressed in equivalents, of a distinct relation being traced to the composition of the compounds from which these products have been derived. It is to the steady application of this principle to the investigation of the complicated decompositions of organic compounds, that we must ascribe the amazingly rapid progress which has of late been made in organic chemistry.

It is obvious that where we are unable to trace the relation above mentioned between the products and the substances which yield them, this must be looked upon as a proof that we do not

yet fully understand the changes we are investigating; and that we are either mistaken in the composition which our analyses lead us to assign to one or more of the new compounds, or have overlooked some one or more of the products actually formed.

The laws of combination which have been briefly indicated in the foregoing pages, have been deduced from accurate observation, and are nothing more than an abridged expression of facts. They are consequently entirely independent of any theory or explanation of their causes which may be attempted. Neither is it necessary to attempt any such theory or explanation, since, for all practical purposes, the facts alone are required.

But the human mind is never satisfied with observing and ascertaining facts, and deducing from them those general expressions which are called laws of nature. Man ever strives to account for, to explain, that which he has observed: and although his explanations never reach the essence of things, but only enable him to generalize to a greater extent, and to approach somewhat more nearly the Great First Cause of all, still it appears to be a law of his intellect, that he shall never cease from his attempts to explain, by reference to some simple principle, the complicated phenomena by which he is surrounded.

The facts of gravitation are well known, and entitle us to admit the law, that all material bodies have a tendency to move toward each other with a force which is proportional to their masses, and which varies inversely as the squares of their distances. To account for this, we are in the habit of assuming the existence of a certain force which we call the attraction of gravitation. But we know nothing of the nature of this force; and, assuming its existence, it is only known to us by its effects. Nor does the assumption enable us to understand *how, in what way*, it acts in attracting masses of matter toward each other.

But if we assume the existence of such a force, acting according to the above law, then we can deduce, as necessary inferences from these data, all the phenomena which have been observed, and many which have not been observed, but which we are thus enabled to anticipate. There is, therefore, an obvious advantage in assuming the existence of this supposed cause, as we are thus enabled to remember and to classify the phenomena much better than in the form of a dry catalogue of facts, not attached to any common idea.

If, in like manner, we seek for some hypothesis which shall account for the facts of combination in definite and multiple proportions, the first obvious conclusion is that the cause of these phenomena must be intimately connected with the mechanical constitution of matter. But since our senses are not capable of directly taking cognizance of the ultimate physical constitution of matter, and since the ultimate causes of natural phenomena are

also beyond the reach of our senses, we must have recourse to induction from facts, or to some hypothesis regarding the constitution of matter, which may serve to explain the phenomena.

Different opinions have been held as to the constitution of matter; but two in particular have prevailed. According to one, matter is susceptible of being divided *ad infinitum*: according to the other, matter is formed of particles, which are indeed very minute, far too minute to be cognizable by our senses; but which still possess a definite size, and cannot be divided. They are hence called *atoms*.

Now it is very remarkable that if we assume the latter view, or that which is called the atomic constitution of matter, to be correct, and if we further assume that the individual atoms of different elements possess different weights, but always the same weight in the same element, we can, from these data, deduce all the facts of combination in definite and multiple proportions. This is the theory proposed by Dalton — The Atomic Theory.

No other hypothesis hitherto proposed is capable of explaining the phenomena; and therefore in the present state of our knowledge, and until a better explanation shall be given, we may admit the atomic theory. It is to be observed, however, that we have no positive proof of its truth, nor are we likely to obtain such proof. On the other hand, the discovery of any fact inconsistent with the atomic theory would compel us to reject it, even if we had no other theory to supply its place. But whether the atomic theory be admitted or not, the facts of combination in definite and multiple proportions remain unaffected.

ATOMIC THEORY.

According to the atomic hypothesis, therefore, matter is composed of certain minute, indivisible particles, or atoms; and consequently cannot be divided infinitely. We may divide a mass of matter to a very great extent, far beyond the point at which our senses cease to be able to follow; but still there is a limit to divisibility, and we should reach that limit if we succeeded in dividing so far that the resulting particles were the individual atoms.

Here it may be observed, that the partisans of the opinion according to which matter is infinitely divisible, argue thus: there is no conceivable particle of matter so small that we cannot conceive it to be divided into two halves, and so on *ad infinitum*; therefore there is no limit to the divisibility of matter.

Now while we admit that there is no limit to *our conception* of the divisibility of matter, this does not prove that there may not be a limit, in point of fact, to its actual divisibility. For let us consider a moment what division really is; and we shall find that it can only be defined as the separation of one portion of matter from others. Now as matter, in its usual forms, undoubtedly

consists of particles held together, more or less firmly, by cohesion, it is plain that we can easily, by overcoming cohesion, separate those particles from each other; and this is ordinary division.

But, on the atomic hypothesis, each of these visible ordinary particles is, like the original mass, formed of still smaller particles cohering together, but, in neither case, in absolute contact. Indeed, the phenomena of expansion by heat, and contraction by cold, demonstrate that the particles of matter are not in absolute contact: in other words, an ordinary mass of matter may be defined as *a portion of space not entirely filled with matter*.

Let us now define an atom as *a portion of space entirely filled by matter*, and we see at once that such a mass cannot possibly admit of division. It is strictly a unit, and as division implies separation of one unit from another, it is here evidently impossible. It is not meant that we can prove this to be the nature of atoms, for we cannot even prove their existence: but the object of the above illustration is to show that we can conceive the existence of an indivisible particle, and therefore that the argument above described in favor of the infinite divisibility of matter is not necessarily conclusive.

Such a particle or atom as has now been defined, or, in other words, a single portion of matter entirely filling the space bounded by its circumference, cannot be cut in two like a mass of matter, for there is no interstice into which, as in ordinary matter, the edge of a cutting instrument can penetrate; and it cannot, being a unit, be separated from itself. It cannot be crushed to powder, for the particles of a powder existed previously as distinct particles, in the solid mass of matter, and were only separated by the force employed. It cannot be drawn out like metal into wire, or beat out into thin leaves; for both drawing out and beating out are merely new *arrangements* of a plurality of particles, and we have here only a unit.

Moreover, such a particle or atom would, in all probability, be spherical, since no reason can be assigned why one dimension should exceed another. It would no doubt be opaque; for transparency is the result of the passage of light through the vacant spaces between the particles of matter: and colorless, because color depends on the action of the particles of matter on light; and it would be perfectly hard.

In short, it is evident that we can imagine indivisible atoms to exist; and that the physical properties of matter are not in any degree inconsistent with the idea that it is made up of such atoms.

The atomic hypothesis goes on to assume that the atoms of the different elements possess different weights, but that those of the same element possess invariably the same weight.

The third assumption is, that when one element unites with another, the atoms of the two respectively combine. Thus, an

atom of A combines with an atom of B, to form an atom of the compound AB. Or two atoms of A unite with three atoms of B, to form an atom of the compound AABBB.

A distinction must here be made between simple or elementary atoms and compound atoms. It is obvious that an atom of AB, if it contain an atom of A and an atom of B, may be decomposed, and A separated from B. AB is, therefore, not an atom in the fullest sense of the word. But A cannot be separated from B by mechanical means, or otherwise than by chemical agency; so that, in a mechanical sense, AB is an atom, although a compound one. A mass of the compound AB is made up of mechanically indivisible, but chemically divisible, particles of AB, each of which, although it may be called an atom, contains an atom of each of the elements.

The *absolute* weight of the atoms of the different elements is altogether unknown. If, indeed, we had any means of ascertaining the number of atoms in a given weight of any element, in one grain for example, we should know the actual weight of each atom; but this is for the present beyond our power.

But we know the relative weights of two elements which combine to form a given compound; and, therefore, if we assume that the compound contains one atom of each element, we know at once the *relative* weights of the atoms of those elements. Thus, 8 grs. of oxygen unite with 1 gr. of hydrogen to form 9 grains of water; and we assume that water contains 1 atom of each element, or an equal number of atoms of each. In that case it is clear that the relative weights of the single atoms must be the same as those of what are assumed to be equal numbers of each; and, consequently, 1 atom of oxygen will be eight times heavier than 1 atom of hydrogen. If the 8 grains of oxygen contain 8,000,000 of atoms, then 1 atom of oxygen would weigh $\frac{1}{8,000,000}$ of a grain, and 1 atom of hydrogen $\frac{1}{80,000,000}$ of a grain. But although we shall most probably never know the actual number in a given weight, or the absolute weight of the atoms, we are not the less sure that, if matter be composed of atoms, differing in weight for each element, and if water be formed by the union of an equal number of atoms of oxygen and hydrogen, then 1 atom of oxygen must be eight times heavier than 1 atom of hydrogen.

These numbers, then, express merely the relative weights of these atoms: on the above assumptions, 8 represents the weight of an atom of oxygen, if an atom of hydrogen be supposed to weigh 1; and 12.5 will represent the weight of an atom of hydrogen, if an atom of oxygen be supposed to weigh 100. It is evident that any other numbers might be used, provided the ratio, in this case that of 8 to 1, were kept up.

It is now easy to see, that the atomic hypothesis, if assumed, at once explains all the facts of combination in definite and multiple

proportions. As has already been remarked, no other hypothesis, yet proposed, is capable of doing this; and, therefore, while we must not lose sight of the fact that the atomic hypothesis has not been, and indeed probably never will be, demonstrated to be true, we are justified in adopting it until it shall be proved to be false, or until a better one shall be proposed in its stead.

It will be observed that the weights of the atoms, or atomic weights, as they are termed, coincide with the equivalent numbers previously given. When, therefore, the term atomic weight is used, it is not as implying the established truth of the atomic theory, but only as a convenient synonym for the term equivalent, or for that of combining proportion. Whichever name we use, it must never be forgot that the facts remain unchanged, and are independent of all hypothesis. 9 grains of water invariably contain 8 of oxygen and 1 of hydrogen, whether we speak of the combining proportions, the equivalents, or the atomic weights of oxygen and hydrogen being represented by the numbers 8 and 1. The two former expressions have the advantage of simply expressing the fact without any allusion to hypothesis, and are, therefore, strictly speaking, preferable; but the latter is much used, and may safely be employed when properly defined.

In this country, the terms equivalent and atom have been from the beginning held to be entirely synonymous. On the Continent, this has not been the case: for the equivalent of many elements, such as hydrogen, chlorine, &c., has been there assumed to contain 2 atoms; and hence the atomic weight of hydrogen, for example, has been on the Continent one-half of that adopted here.

This is a matter which is, to a great extent, arbitrary, and only affects the mode of viewing and representing the composition of certain compounds. Thus Continental chemists, admitting as we do that 9 grains of water contain 8 of oxygen and 1 of hydrogen, consider water to be composed of 1 atom of oxygen and 2 atoms (= 1 equivalent) of hydrogen; they, consequently, give to hydrogen the atomic weight of 0.5, that of oxygen being 8; or 6.25, that of oxygen being 100.

It is not easy to decide whether water be composed of 1 *atom* of each element, or of 1 *atom* of oxygen to 2 *atoms* of hydrogen. But as both parties agree that water contains 1 *equivalent* of each element, it is obvious that the system adopted in Britain, by which equivalent is made entirely synonymous with atom, has the very great advantage of superior simplicity; and that system will, therefore, be followed in this work. Within the last year or two, several of the most distinguished chemists on the Continent have adopted the British system in this respect, and there is little doubt that it will, ere long, become universally prevalent.

The table of equivalents, formerly given, is, therefore, at the same time, a table of atomic weights. It is now time to give rules

for the use of that table, and particularly for the use of the abbreviations or symbols there attached to the elements, in the construction of formula.

CHEMICAL SYMBOLS AND FORMULA.

These have nothing in common with algebraical symbols and formula. They are mere abbreviations, and are intended to express only the arithmetical operations of addition and subtraction. Various systems have been given to the world: but that which has finally obtained the most extensive currency among the chemists of the day, is one proposed by Liebig and Poggendorff, which we now proceed to explain.

The symbol of an element, standing alone, signifies 1 atom, or equivalent, of the element. Thus O stands for 1 atom of oxygen, H for 1 atom of hydrogen, and Fe for 1 atom of iron (ferrum.)

A symbol, with a small figure below and to the right, signifies as many atoms of the element as the figure expresses. Thus O_2 means 2 atoms of oxygen, S_5 , 5 atoms of sulphur.

Two symbols joined by the sign +, or simply placed together, signify a compound of 1 atom of each element. Thus $H + O$, or simply HO , means water, a compound of 1 atom hydrogen, and 1 atom oxygen.

If a figure be attached, as above, to either or both symbols, it multiplies that symbol only to which it is attached. Thus $Mn O_2$ is the symbol for peroxide of manganese, a compound of 1 eq. manganese and 2 eq. oxygen. $Cu_2 O$ is the symbol of suboxide of copper, composed of 2 eq. copper and 1 eq. oxygen. $Fe_2 O_3$ is the symbol of peroxide of iron, which contains 2 eq. of iron and 3 eq. of oxygen.

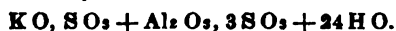
When a compound, formed of two or more compounds, is to be expressed, the compounds which combine are joined, either by a + sign or by a comma. Thus $HO + SO_2$, or HO, SO_2 , both signify hydrated sulphuric acid, a compound of 1 eq. water and 1 eq. dry sulphuric acid.

A large figure, printed on the same level as the symbol, and to the left of it, multiplies every symbol as far as the next comma, or the next + sign; or it multiplies all within brackets if placed before them. Thus $2HO$ means 2 atoms of water, $2SO_2, KO, HO$, represents bisulphate of potash, a compound of 2 eq. sulphuric acid, 1 eq. potash, and 1 eq. water. It might also be written $2SO_2 + KO + HO$. But the following, $2(SO_2, KO, HO)$ would signify 2 eq. of a compound which was formed of 1 eq. sulphuric acid, 1 eq. potash, and 1 eq. water.

When a compound contains 3 or more elements, the symbols are written simply one after the other, with the necessary figures. Thus, sugar is represented by $C_{12}H_{12}O_{10}$: that is, 12 eq. carbon, 10 eq. hydrogen, and 10 eq. oxygen. Alcohol is $C_4H_6O_2$.

If we wish to show that any compound of three or more elements really contains two compounds, it is expressed in the following manner: alcohol, $C_4 H_8 O_2$, when viewed as a compound of ether and water, becomes $C_4 H_8 O + H_2 O$. Benzoic ether, $C_{10} H_{10} O_4$, becomes $C_7 H_6 O_2$ (benzoic acid) + $C_3 H_4 O$ (ether).

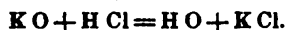
In this way we find it quite easy to express in symbols the composition of the most complicated substances. For example, crystallized alum is composed of 1 eq. neutral sulphate of potash, 1 eq. tersulphate of alumina, and 24 eq. of water of crystallization. This is expressed in symbols, as follows:



And this abbreviated expression contains, in a line, in addition to the general information concerning alum printed above, more information as to details than could be given in a page of print. It informs us, for example, that alum contains 4 eq. sulphuric acid, of which 1 is combined with 1 eq. of potash, and 3 with 1 eq. of alumina: that alumina is a sesquioxide of aluminum: that 1 eq. alum contains 1 eq. potassium, 2 eq. aluminum, 4 eq. sulphur, 24 eq. hydrogen, and 40 eq. oxygen, &c. &c. &c.

There are, besides the direct information thus conveyed by symbols, two most important uses to which they are applied.

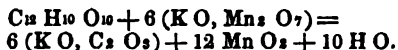
The first is, to render easily intelligible the view taken by a writer of any chemical change, however complicated. This is done by means of a formula or equation: in which all that is essential is, that the sum of the various symbols should be the same on both sides. Thus, to take an example previously described in words (at p. 19), the action of oxide of potassium on hydrochloric acid. This is expressed in a formula as follows:



Here the symbols on the left are those of the bodies which act on each other, oxide of potassium and hydrochloric acid; while those on the right are the symbols of the new compounds produced, water and chloride of potassium.

Or, to take a more complicated case.

Sugar, $C_{12} H_{10} O_{10}$, when acted on by 6 eq. of hypermanganate of potash, $K O, M n_2 O_7$, gives rise to 6 eq. of oxalate of potash, $K O, C_2 O_3$, 12 eq. of peroxide of manganese, $M n O_2$, and 10 eq. of water. All this is briefly and clearly expressed by the equation



The second very important use to which these equations are applied is, that of calculating the quantities of the different substances which must be employed, in order to operate as economically as possible, and likewise the weight of the products which

ought to be obtained. Thus, in the last example, we wish to know what proportions of sugar and hypermanganate of potash ought to be used, that nothing of either should be wasted; and also how much oxalate of potash, peroxide of manganese and water will be obtained. By means of the above equation, and the table of atomic weights, we can easily make all these calculations. Since the equivalent or atomic weight of a compound is the sum of those of its elements, it is obvious that the equivalent of sugar is equal to the sum of 12 eq. of carbon + 10 eq. hydrogen + 10 oxygen. Now, by the table, the equivalent of carbon is 6, that of hydrogen 1, that of oxygen 8. Hence the equivalent of sugar is $= 6 \times 12 + 1 \times 10 + 8 \times 10 = 72 + 10 + 80 = 162$. In like manner the equivalent of hypermanganate of potash is found to be, in round numbers, 160. For every 162 parts, therefore, of sugar, we must employ 6 times $160 = 960$ parts of hypermanganate of potash. The whole materials employed amount to 1122.

On the other hand, we obtain of oxalate of potash, the equivalent of which is (in round numbers) 84, 6 equivalents $= 504$; of peroxide of manganese, the equivalent of which is 44, 12 equivalents $= 528$; and of water, the equivalent of which is 9, 10 equivalents $= 90$; the whole products amounting to 1122.

It is hardly possible to exaggerate the value of so easy a method of representing chemical changes, and of making all the necessary calculations connected with them. Every chemist, and every student of chemistry, ought to be quite familiar with the use of chemical formula; and, indeed, without this knowledge it will soon be impossible to read chemical writings. The use of formula enables the writer so easily to put before his readers, in a very small space, any conceivable view of the phenomena, such as might require pages to explain in words, that they are now universally employed.

Even in the commonest use of symbols and atomic weights, that, namely, of expressing the composition of any compound, the advantage derived from their employment is immense. Thus, previous to the invention of tables of atomic weights, chemists could only express the composition of a compound by giving the proportions of the elements contained in 100 parts. For example, water, the protoxide of hydrogen, was found to consist of—Hydrogen, 11.11; and oxygen, 88.88, in 100 parts; while the deutoxide of hydrogen was found to consist of—hydrogen, 5.89; and oxygen, 94.11, in 100 parts. It is very difficult for the memory to retain these numbers with accuracy, even in the case of a few such compounds; how much more so, then, must it be to remember the composition of the numerous bodies with which the chemist is constantly occupied?

If however, we have recourse to symbols, we have only to express the composition of water by $H O$, and that of the deutoxide of hydrogen by $H O_2$; and referring to the table of atomic

weights, we find that the former contains one of hydrogen to 8 oxygen, and the latter, 1 of hydrogen to 16 of oxygen. Even if we could not retain these latter numbers, we should thus still derive great benefit from the use of symbols; but the fact is, that we soon learn the atomic weights of the more important elements, and are not compelled to have recourse to the table for them.

But this is not all; for in the numbers, as given in 100 parts, we can trace no relation; and, consequently, if we commit them to memory, must do so as bare numbers. In the symbols, on the contrary, we see at a glance that the same quantity of hydrogen which, in water, is combined with a given weight of oxygen, is combined with double that weight in the deutoxide of hydrogen; and we are thus supplied, not only with a fact, in itself of the highest value, but also with a link by which the composition of two substances is associated in the memory, and therefore retained with facility.

Before quitting this part of the subject, it is well to point out two results which follow from the atomic theory.

The first is, that since, by definition, an atom is that which cannot be divided, there cannot be formed a compound of 1 atom, or equivalent of one element, and $\frac{1}{2}$ an atom (or any fractional number of atoms, as $1\frac{1}{2}$, $2\frac{1}{2}$, &c.) of another element. Should such proportions appear to exist, they must be so expressed as to get rid of fractions, otherwise they imply a contradiction in terms. Thus, for example, iron combines with oxygen in two proportions. In the first compound, or protoxide of iron, 28 parts (1 eq.) of iron are combined with 8 parts, or 1 eq., of oxygen. We, therefore, assume this compound to contain 1 atom of each element, and express it in symbols by Fe O. In the other oxide, or peroxide of iron, 28 parts, or 1 eq., of iron are found to be combined with 12 parts of oxygen. Now, 8 being 1 eq. of oxygen, 12 must be $1\frac{1}{2}$ eq. But as it would be absurd to call this oxide a compound of 1 atom of iron and $1\frac{1}{2}$ atoms of oxygen, we get rid of the fraction by doubling both numbers, and we represent the peroxide of iron by Fe₂ O₃. Here the proportion is still that of 1 to $1\frac{1}{2}$, but the absurdity of dividing an atom is avoided. It is obvious that the atomic weight of the compound is double what it would be if we had retained the fraction; for Fe₂ = 56, and O₃ = 24: and 56 : 24 :: 28 : 12. As the proportion is still that of 1 to $1\frac{1}{2}$ atom, although there are in reality, 2 to 3, this compound is frequently called sesquioxide of iron, from *sesqui*, a prefix signifying one and a half. The prefix, *sesqui*, is used in many similar cases, precisely in the same way.

Of course, where analysis indicates the proportions of 1 atom of A to $2\frac{1}{2}$ or $3\frac{1}{2}$ of B, we, in like manner, to avoid fractions, express these proportions by 2 to 5, or by 2 to 7. The symbol for phosphoric acid is P O₅: that of hypermanganic acid is Mn O₇.

The second result or corollary from the atomic theory, is, that when two compounds having a common element unite together, the amount of the common element in the equivalent of the one is, to its amount in the equivalent of the other, in a ratio which may be expressed by whole numbers. Thus, potash is composed of potassium and oxygen, sulphuric acid of sulphur and oxygen. Here oxygen is the common element. Now, in an equivalent of potash, KO , there is one atom of oxygen = 8. In an equivalent of sulphuric acid, SO_2 , there are 3 atoms of oxygen = 24; and it is obvious that the oxygen in the latter is to that in the former as 3 : 1. This relation is at once seen in the formula of the compound, sulphate of potash, which is KO, SO_2 ; and it prevails necessarily in all neutral compounds of sulphuric acid with bases which have an analogous constitution. In nitrate of potash, KO, NO_3 , the ratio is different, being as 5 : 1. When an acid, such as sulphuric acid, forms a neutral salt with a base of a constitution different from that of potash, as, for example, with sesquioxide of iron, the relation of 3 to 1 is still kept up: for the neutral sulphate of sesquioxide of iron is $\text{Fe}_2 \text{O}_3, \text{SO}_3$. In a compound not neutral, such as $\text{Fe}_2 \text{O}_3, \text{SO}_3$, which represents the basic sulphate of sesquioxide of iron, the relation is different, being that of 3 : 3 or 1 : 1; but still it is capable of being expressed in whole numbers.

COMBINATION BY VOLUMES.

When two gaseous bodies combine together, it is always in such proportions, by volume, that 1 volume of the one gas combines with one or two or more volumes of the other; and if the resulting compound be gaseous, its volume bears some simple ratio to those of its elements. Thus, 1 vol. hydrogen combines with 1 vol. chlorine, to produce 2 vol. hydrochloric acid; and 2 vol. hydrogen combine with 1 vol. oxygen, to form 2 vol. of the vapor or gas of water. It is evident, that where two gases combine in several proportions, the law of multiple proportions must prevail in regard to the volumes, as well as in regard to the weights. For example, in the five compounds of nitrogen and oxygen formerly mentioned, 2 vol. nitrogen are combined with 1, 2, 3, 4, and 5 vol. oxygen.

The volume of the compound is in all cases either equal to the sum of the volumes of its component gases, or less than that sum: in the latter case condensation has taken place. It follows that 1 vol. of a compound gas contains either 1 vol. of each of its constituents, or a multiple or a submultiple of a volume of one or both.

It is easy to see that there must be a relation between the volume and the weight of gaseous elements, since the law of definite proportions can be traced in both. Since water, for

example, is composed of 8 parts *by weight* of oxygen to 1 of hydrogen, and of 2 parts *by volume* of hydrogen to 1 of oxygen, it must be possible to construct a table of combining volumes, as well as a table of atomic weights; and in fact this may be done in regard to all those elements which may be made to assume the form of gas, and even in regard to some which cannot be obtained in that form, but which combine with gaseous elements to form gaseous compounds.

If the weight of a given volume of oxygen be called 1.000, it will be found that an equal volume of hydrogen will weigh sixteen times less, or 0.0625; and these numbers will represent the relative specific gravities of these gases. But we already know that in water 1 vol. of oxygen is combined with 2 vols. hydrogen; or, taking the specific gravities, 1.000 oxygen with $2 \times 0.0625 = 0.125$ hydrogen. Now these latter numbers are precisely the atomic weights or equivalents of oxygen and hydrogen, oxygen being made the standard, and = 1.000. Again, 1 vol. hydrogen combines with 1 vol. chlorine, to form hydrochloric acid. Now if one vol. hydrogen as above, be represented as weighing 0.0625, 1 vol. chlorine will be found to weigh 2.25; and these numbers are to each other precisely in the ratio of the equivalents of the two gases, which, on the oxygen scale, are 12.5 and 450, or on the hydrogen scale 1 and 36.

It was for a long time supposed, especially among Continental chemists, that equal volumes of the simple gases contained equal numbers of atoms. Were this the case, the specific gravities of the gases, compared to oxygen as a standard, would of necessity coincide with the atomic weights as compared with the same standard: and would at all events, whatever standard might be employed, bear the same ratio to each other. Specific gravity in the gaseous form and atomic weight, would then be synonymous.

Experiment, however, has demonstrated that this is not the case; but that, while an equivalent of one element is represented by one volume of its gas, two volumes are required to make an equivalent in some cases: and one-half volume, one-third volume, or even less, in others. In the following table will be found the specific gravities or the weights of equal volumes of such elements as admit of their specific gravities being either directly taken or calculated. In the first column are given the usual specific gravities compared to atmospheric air as the standard: in the second, the specific gravities compared to hydrogen as the standard, in order to show the relation to the atomic weights.

It will be observed that the numbers in the second column are not the same, in all cases, as the equivalent numbers of the elements; but many of them are so, and in these cases a volume represents an equivalent. The other numbers are multiples by a whole number of the equivalent, oxygen being represented, for

example, by $16 = 2 \times 8$, and sulphur by $96 = 6 \times 16$. This shows that if an equivalent of hydrogen, chlorine, be represented by 1 vol., an equivalent of the oxygen is represented by $\frac{1}{2}$ vol., and an equivalent of sulphur by $\frac{1}{6}$ vol.

Gas or Vapor.	Specific Gravities.		Chemical Equivalents.	
	Air = 1.	Hydrogen = 1.	By Vol.	By Weight.
Hydrogen	0.0690	1.00	100	1.00
Nitrogen	0.9727	14.12	100	14.15
Carbon (hypothetical)	0.4213	6.12	100	6.12
Chlorine	2.4700	35.84	100	35.42
Iodine	8.7011	126.30	100	126.30
Bromine	5.3930	78.40	100	78.40
Mercury	6.9690	101.00	200	202.00
Oxygen	1.1025	16.00	50	8.00
Phosphorus	4.3273	62.80	25	15.70
Arsenic	10.3620	150.80	25	37.70
Sulphur	6.6480	96.48	16.66	16.10

The knowledge of the proportions by volume, according to which bodies combine, and of the specific gravity of gaseous bodies, enables us to answer a great many questions, and decide a great many doubtful points in chemistry. Thus—

1. If we know the specific gravity of two simple gases and the proportions by volume in which they combine, we can calculate the composition, by weight, of the compound. Thus, 2 vols. of hydrogen combine with 1 vol. of oxygen, to form water. Now, the Sp. G. of hydrogen (Air = 1.000), is 0.0694, and that of oxygen is 1.1111. Therefore water is composed, by weight, of $0.0694 \times 2 = 0.1388$ of hydrogen, and 1.1111 of oxygen.

2. If we know the volumes of the elements of a compound, and their specific gravities, and the volume of the compound, we can calculate the Sp. G. of the compound. To take the same example, 2 vols. hydrogen, Sp. G. = 0.0694, and 1 vol. oxygen, Sp. G. = 1.1111, combine to form 2 vols. vapor of water. Now the vapor of water must weigh as much as the oxygen and hydrogen taken together, that is $0.0694 \times 2 + 1.1111 = 1.2499$. But as this represents the weight of 2 vols. vapor of water, the weight of 1 vol. vapor of water (or the specific gravity) must be $1.2499 \div 2 = 0.6249$.

3. If we know the volume and the Sp. G. of one of the two elements of a binary compound, and the Sp. G. of the compound itself, we can calculate the composition, by weight, of the compound. Thus, 1 vol. carbonic acid gas contains 1 vol. of oxygen; the Sp. G. of carbonic acid gas is 1.5239, and that of oxygen as before is 1.1111. Subtracting the latter number from the former, we have 0.4128, which must represent the weight of carbon

united with 1.1111 of oxygen; and this is the composition, by weight, of carbonic acid gas.

4. If we know the specific gravity of a compound and its composition by weight, we can calculate the composition by volume. Example: By experiment the Sp. G. of the vapor of aldehyde (the weight of 1 vol.) was found to be 1.532; and the analysis of the compound showed that its composition by weight was, carbon 55.024, hydrogen 8.983, and oxygen 35.993, in 100 parts. Now, in order to ascertain the composition by volume, let us calculate the proportions of carbon, hydrogen, and oxygen, in 1.532.

If 100 parts contain 55.024 carbon,	1.532 contain 0.84279
" " 8.983 hydrogen	" 0.13760
" " 35.993 oxygen	" 0.55130

Now the specific gravity or weight of 1 vol. of carbon is hypothetical or calculated; it is assumed to be 0.42139 (see table:) 1 vol. of hydrogen weighs 0.0694, and 1 vol. oxygen weighs 1.1111. It is easy to see, therefore, that 1 vol. of the vapor of aldehyde contains:

2 vols. vapor of carbon	0.84279
2 vols. hydrogen	0.1388
$\frac{1}{2}$ vol. oxygen	0.5555

It is obvious, therefore, that the knowledge of the volumes in which gaseous bodies combine, and of their specific gravities, is of great value to the chemist; but we must not forget that we have no evidence that equal volumes of different elements contain an equal number of atoms; or, in other words, that the term volume may be substituted for atom or equivalent, as was at one time supposed. On the contrary, all the recent researches on this point go to prove that, in the case of many elements, a volume corresponds to two or more equivalents.

ATOMIC OR EQUIVALENT VOLUMES.

The relation between the atomic weight and the specific gravity of bodies in the gaseous form has been briefly indicated in the preceding section. But the subject admits of being considered under different points of view, according to the notions entertained of the atomic constitution of gases. On the supposition, for example, that the atoms, or ultimate particles of all elementary gases, with their surrounding spheres of heat, possess the same volume, all such gases would contain, in equal volumes, the same number of atoms. But as it is certain, that compound gases do not, in all cases, contain the same number of atoms in equal volumes, it is quite possible that elementary gases may also differ in this respect; and, as above stated, the combining volumes of sulphur and of some other elements agree with this conclusion.

It is therefore generally admitted that equal volumes of different elementary gases contain different numbers of atoms; that, for example, 1 vol. oxygen contains twice as many atoms, and 1 vol. sulphur (in the form of gas) six times as many atoms as 1 vol. hydrogen, 1 vol. nitrogen, or 1 vol. chlorine.

This obviously implies that the atoms, with their spheres of heat, are of different sizes; and, to take the cases above mentioned, that the atoms of oxygen gas are $\frac{1}{2}$ the size, and those of sulphur $\frac{1}{6}$ the size of the atoms of hydrogen, nitrogen, chlorine, &c. This is what is called the *atomic volume* of gases. It is not meant that we can ascertain the absolute volume of the atoms, but the relative or comparative volume of the atoms or particles of two or more gases.

Now, since the specific gravity of a gas depends on the number of atoms in a given volume, and on the weight of these atoms, it is evident that the atomic weight, divided by the specific gravity, must give the (relative) atomic volume.

For example, let hydrogen be taken as the standard for the specific gravity of gases, as it is for their atomic weights, then the atomic weight of hydrogen, = 1, divided by its specific gravity, = 1, will yield the quotient 1 for the atomic volume of hydrogen. Again, the atomic weight of oxygen, = 8, divided by its specific gravity, = 16, (that of hydrogen = 1,) gives the quotient 0.5 or $\frac{1}{2}$, as the atomic volume of oxygen; and the atomic weight of sulphur, = 16, divided by its specific gravity as gas, = 96, (that of hydrogen = 1) gives the quotient 0.1666 or $\frac{1}{6}$, as the atomic volume of sulphur.

We thus see, that, on the supposition above adopted that the atoms of different gases differ in size, we can prove that, whatever be the size of an atom of hydrogen gas, an atom of oxygen gas must be half, and that of an atom of sulphur gas one-sixth that size.

It is further obvious, that the number of atoms in equal volumes must be inversely as the atomic volume; or that the specific gravity of a gas, divided by its atomic weight, will give the number of atoms in a given volume. Hydrogen being retained as the standard, then we have $\frac{1}{1} = 1$ = the number of atoms in 1 volume of hydrogen: — $\frac{1}{2} = 2$ = the number of atoms in 1 vol. oxygen: and $\frac{1}{6} = 6$ = the number of atoms in 1 vol. gas of sulphur.

More briefly, the atomic volume and the number of atoms are the inverse of each other: so that we have $\frac{1}{2}$ and 2, $\frac{1}{6}$ and 6, 1 and 1.

If, while we make hydrogen the standard of atomic weights, we make air the standard of the specific gravity of gases, then we obtain, as quotients, a series of numbers equally comparable among themselves, but less simple and easy to retain than the above. We should have, for example, $1 \div 0.0694 = 14.409$ for hydrogen; $8 \div 1.1026 = 7.2554$ for oxygen; and $16 \div 6.9000$

≈ 2.3188 , for the atomic volumes of hydrogen, oxygen and sulphur respectively; and these numbers are to each other as 1, $\frac{1}{2}$, and $\frac{1}{4}$.

In the case of solids and liquids, the relation between atomic weight and specific gravity is far from being so simple, in consequence of the force of cohesion interfering with and disturbing the results. We cannot ascertain whether the atoms of solid bodies have the same size in different bodies, or not; and we cannot tell whether the difference of specific gravity depends on a difference in the number of the atoms, in an equal volume, a difference in the size of the atoms, or a difference in the size of the interstices between the particles, or possibly on two or more of these causes.

Some chemists assume that there are no interstices, but that the atoms wholly fill up the space within the circumference of the body. On this supposition, the atomic weight, divided by the specific gravity (in solids and liquids), must give the atomic volume. It is difficult, however, to admit the absence of interstices or pores in solids and liquids, if we consider them formed of atoms; and it is perhaps better to use the term *equivalent volume* instead of *atomic volume*.

The equivalent volume, then, of a solid or liquid is obtained by dividing the atomic weight (or rather equivalent number) by the specific gravity in the solid or liquid state. Water, the standard for the specific gravity of liquids and solids, may be made the standard of equivalent volumes.

Thus the atomic weight of water, $= 9$, divided by its specific gravity, $= 1$, gives the quotient 9 as its equivalent volume. The atomic weight of potassium, 39.26, divided by its specific gravity, 0.865, gives 45.387 for its equivalent volume; and the atomic weight of carbon, 6.04, divided by its specific gravity in the form of diamond, $= 3.5$, the quotient 1.725 for the equivalent volume of the diamond.

On the other hand, the specific gravity, divided by the atomic weight, gives the relative number of atoms in a given volume; and in the case of potassium this is $0.865 \div 39.26 = 0.0220$; in the case of carbon it is $3.5 \div 6.04 = 0.5794$. Finally, in the case of water, the relative number of atoms in a given volume, which may be made the standard, is $1 \div 9 = 0.1111$. If, for convenience, the number for water is made 1000, then that for potassium becomes 198.0, and that for carbon becomes 5215.

Assuming, likewise for convenience, the equivalent volume of water (the standard) to be (instead of 9) 1000, the equivalent volume of potassium becomes 5043, and that of carbon 191.666.

We thus perceive that the equivalent (or atomic) volume of carbon is about twenty-five times less than that of potassium, and that the number of atoms of carbon contained in a given volume

is about twenty-five times greater than in the case of potassium. This compression of so large a number of atoms into a given volume may be the cause of the great hardness of the diamond.

The whole subject of equivalent volumes is full of interest; but as chemists have only recently begun to study solid and liquid bodies in this point of view, our knowledge on the subject is still very imperfect and limited. For what has lately been done, we are chiefly indebted to Kopp and to Schröder.

Playfair and Joule have very lately published the first part of an elaborate investigation into the volumes occupied by bodies, both in the solid form and when dissolved in water; and they have obtained results of an unexpected nature as well as of very great value.

The reader is referred to their paper in the *Memoirs of the Chemical Society*. Here we have only space to allude to the subject, and to mention that, among other curious results, these chemists have found that many salts, when dissolved in water, do not add to the bulk of the water more than is due to the water actually present in the salts. Thus, for example, alum, 1 eq. of which contains 23 equivalents of the elements, potassium, aluminium, sulphur, and oxygen, besides 24 eq. of water, dissolves in water without increasing its bulk more than the addition of the 24 eq. of water must necessarily do; so that the 23 eq. above mentioned occupy no additional space, and must either be contained in the pores or interstices of the water, or disappear altogether as far as the occupying of space is concerned, if water be supposed to have no pores.

They have further shown that when salts do add to the bulk of the water in which they are dissolved, the increase of the bulk corresponds to that of a volume, or some multiple of a volume, of water. It is evident that these and similar researches must soon greatly extend our knowledge of the mechanical constitution of matter.

ISOMORPHISM.

Most substances, when they assume the solid form slowly, so as to allow the particles to follow their natural attractions, exhibit, more or less perfectly, a regular form: in other words, they crystallize. Thus carbon, when slowly deposited in the form of diamond, assumes the form of a regular octohedron, or of some form geometrically allied to it; and common salt, a compound body, takes the form of the cube and its modifications, including the octohedron.

Now it has been observed that the same substance invariably crystallizes in forms belonging to the same system, but that different substances very frequently present different crystalline forms. Thus, while diamond crystallizes in regular octohedrons, iodine

forms acute rhombic octohedrons: and while common salt crystallizes in cubes, chloride of barium yields right rhombic prisms.

It happens, occasionally, but rarely, that the same element is capable of assuming two crystalline forms, belonging to different systems, and not geometrically connected with each other. Thus sulphur, crystallizing from its solution in bisulphide of carbon, forms very acute rhombic octohedrons, but when melted by heat, and allowed to consolidate by cooling, it yields oblique rhombic prisms.

The same is occasionally observed in compound bodies. Thus, carbonate of lime, in its common form of Iceland spar, crystallizes in obtuse rhombohedrons and in innumerable varieties of that form: but in the rarer form of arragonite, it assumes the form of a rhombic prism.

These cases, and others which are analogous, are to be explained by a different arrangement of particles, dependent most probably on a difference of temperature at the period of the formation of the crystals. They are not, however, numerous enough to affect the general law, that the same substance always assumes the same crystalline form.

But the admirable researches of Gay-Lussac and of Mitscherlich have established the fact, that in many instances, different compounds assume the same form. Thus, the following substances, and many others, take the form of the cube, tetrahedron, or regular octohedron, which are geometrically connected: chloride of sodium (sea-salt), chloride of potassium, sal ammoniac, bromide of potassium, iodide of potassium, sulphide of lead, fluoride of calcium, bisulphide of iron, arseniuride of cobalt, sulphate of alumina and potash (alum), ammonia alum, chrome alum, iron alum, sesquioxide of iron, sesquioxide of aluminum, sesquioxide of chromium. In like manner, other crystalline forms are found to be common to many different compounds, although none occurs so frequently as the cube and its congeners.

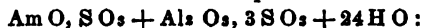
Now, at first sight it would appear that no relation whatever could exist between the form of these numerous and very different compounds, and their composition. But on closer inspection, they are found to arrange themselves into groups. Of these groups, two may be specified among the compounds above enumerated. One is that of the chlorides, bromides, iodides and fluorides of metals, having the formula MR , that is, 1 at. metal to 1 at. radical. This includes chloride of potassium KCl , of sodium $NaCl$, of ammonium (sal ammoniac) $AmCl$:* to which may be added bromide of potassium KBr , iodide of potassium KI , and fluoride of calcium CaF ; and this group is a very large one. It will be observed that the members of it contain an equivalent of a metal

* See the section on Ammonium.

united to 1 equivalent of a metalloid, and are, therefore, so far analogous in composition. The next group is that of the alums. Common alum has this formula :



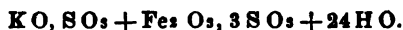
Now if we substitute ammonium for potassium, we have



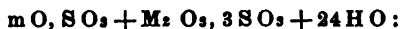
and this is the formula of ammonia alum. Chrome alum is



and another may be formed by substituting Am for K. Iron alum is



And here also another alum is obtained by substituting Am for K. A good many more alums may be procured by substituting Na (sodium) for K, and Mn for Al, that is, manganese for aluminum; and all these salts have the same crystalline form and the same general properties. Here, as in the former more simple group, the analogy in constitution is at once obvious. Every alum is



m stands for a metal of one class, such as potassium, sodium or ammonium; and M for a metal of another class, such as aluminum, iron, chromium or manganese. It appears, therefore, that a salt, containing 1 eq. of a neutral sulphate of a protoxide of one of the former metals ($m O, S O_3$), along with 1 eq. of a neutral tersulphate of a sesquioxide of one of the latter metals ($M_2 O_3, 3 S O_3$), and 24 eq. water ($24 H O$) takes the crystalline form of common alum, the type of this group. From this we must conclude that the similar *arrangement* of particles prevailing in all these alums is one chief cause of the similarity in form. We see that the particles need not be all identical in two similar crystals; for example, of common alum and of iron alum. But there must be an analogy between those elements the equivalents of which may be mutually substituted for each other. We find, accordingly, in all other relations an analogy between potassium, sodium and ammonium, on the one hand, and between aluminum, iron chromium and manganese on the other. In the group first mentioned, that of the chlorides, bromides and iodides of certain metals, we find the same analogy between potassium, sodium and ammonium on the one side, and between chlorine, bromine and iodine on the other.

Now, to these groups of analogous elements, the name of isomorphous groups has been given, as there is every reason to believe that, as elements, they possess the same form (*see*, equal, and *proper*, form): and the phenomena of identical form in compounds of different but analogous composition, have received the name of isomorphism. Two elements are isomorphous, which either crys-

crystallize in the same form, or may be substituted for each other in their compounds, equivalent for equivalent, (the other elements remaining unchanged), without affecting the form of the compound.

The doctrine of isomorphism enables us, in many cases, to decide on the formula of a compound, and, consequently, on its equivalent. Thus, we have seen that aluminum or iron may be replaced by chromium, without change of form, in alum; and we find that sesquioxide of aluminum, sesquioxide of iron, and oxide of chromium, also crystallize in the same form. Now, the composition of oxide of chromium was formerly uncertain; but, finding as we do that it is isomorphous with the other two sesquioxides, we conclude that it is also a sesquioxide, and that its formula is Cr_2O_3 .

Again, chromic acid is found to contain twice as much oxygen for the same amount of chromium, or it may be represented as Cr_2O_5 . This being a most improbable formula, we observe next, that chromic acid may be substituted for sulphuric acid, without change of form; in other words, these acids are isomorphous. But the formula of sulphuric acid is SO_3 , and we, therefore, conclude, that the formula of chromic acid is CrO_3 ; which agrees perfectly with the first observation, that it contains twice as much oxygen for the same weight of chromium as the oxide does; for CrO_3 is the very same proportion as Cr_2O_3 .

The following isomorphous groups have been established, and the existence of more is highly probable:—

1.		7.	
Silver	Ag	Salts of potash	K O
Gold	Au	Salts of oxide of ammonium	Am O
2.		(Or ammonia NH_3 + water, $\text{H O} = \text{NH}_2\text{O}$)	
Arsenious acid (in its unusual form)	As_2O_3	8.	
Sesquioxide of antimony	Sb_2O_3	Oxide of silver	Ag O
3.		Oxide of sodium	Na O
Alumina	Al_2O_3	9.	
Sesquioxide of iron	Fe_2O_3	Baryta	Ba O
“ chromium	Cr_2O_3	Strontia	Sr O
“ manganese	Mn_2O_3	Lime (in arragonite)	Ca O
4.		Oxide of lead	Pb O
Phosphoric acid	P_2O_5	10.	
Arsenic acid	As_2O_5	Lime (in Iceland spar)	Ca O
5.		Magnesia	Mg O
Sulphuric acid	S O_3	Protoxide of iron	Fe O
Selenic acid	Se O_3	“ manganese	Mn O
Chromic acid	Cr O_3	“ zinc	Zn O
Manganic acid	Mn O_3	“ cobalt	Co O
6.		“ nickel	Ni O
Hypermanganic acid	Mn_2O_7	“ copper	Cu O
Hyperchloric acid	Cl O_7	“ lead (in plumbo calcite)	Pb O

The above groups are almost all formed of compounds; either because these compounds are found to be actually isomorphous when themselves crystallized, as, for example, the sesquioxides in group 3; or because they may be mutually substituted for each other, in those compounds into which they enter, without change of form. This, as we have seen, is the case with the sesquioxides in the alums; and, indeed, three of these oxides have been obtained in crystals, and found to be themselves isomorphous. But it is also the case with the acids—for example, in groups 4 and 5; although we do not positively know, what is, however, most probable, that these acids possess, in each group respectively, the same form. Although, for example, we cannot say that arsenic and phosphoric acids are themselves isomorphous, since they do not crystallize, yet their salts are strictly isomorphous; and the analogy extends not only to form, but to color, taste, and many other external qualities. So strong, indeed, is this external resemblance, that, in many cases, we must actually decompose one of these salts, and ascertain whether it contain arsenic or phosphorus; before we can say whether the salt is an arseniate or a phosphate. The same extraordinary similarity in all external characters, is seen in the salts of the sulphuric and selenic acids.

We can hardly doubt that not only the salts, but the acids, are really isomorphous, and would be found so, if we could obtain them all in crystals; and we have the same reason to conclude that the elements of these acids are also isomorphous; that arsenic and phosphorus, sulphur and selenium, for example, crystallize in the same form.

Indeed, the only plausible explanation of the existence of isomorphous groups of compounds is, that the elements characterizing those groups are isomorphous, and that hence their analogous compounds are so. If we assume that arsenic and phosphorus are isomorphous, then we see that As O_3 must be isomorphous with P O_3 , since the oxygen in both is, of course, the same. In like manner, arseniate of soda, $\text{As O}_3, 2 \text{ Na O}$; HO , 24 aq., must be isomorphous with phosphate of soda, $\text{P O}_3, 2 \text{ Na O}$, HO , 24 aq., since all the elements in these two salts are the same in nature, number and arrangement, except that As in the first is replaced by P in the second, and the elements As and P have been assumed to possess the same form.

There is one case which requires explanation. It is the isomorphism of potash KO , and oxide of ammonium $\text{NH}_4 \text{ O}$; or, in other words, ammonia with 1 at. water, $\text{NH}_3 \text{ HO}$. Here we have a body composed of 6 equivalents isomorphous with one containing only two. But, on the one hand, there is good reason to believe that the compound metal, ammonium, NH_4 , exists; and if we represent this by a single symbol Am, its oxide will be Am O , corresponding in constitution to K O , each being formed of 1 eq.

metal, and 1 eq. oxygen. It is true, Am is a compound; but, on the other hand, this compound acts as an element, and $\text{Am} = \text{NH}_4$ is only 1 eq. of metal. Besides, we cannot be certain that even potassium, K, is not also a compound, although we have not as yet succeeded in decomposing it, if it be one. At all events, it is a fact, that NH_4 may be substituted for K without affecting the form of the compound in which the substitution is made, as in the alums; and we have only to assume that the compound NH_4 happens to be isomorphous with the simple substance K, and all the facts would follow.

We shall have occasion to return to the subject of isomerism, when treating of salts generally, and of their crystallization.

ISOMERISM.

We have seen that, as a general rule, analogy of composition implies analogy or similarity in form and external properties. But it has been observed in a number of cases, that two or more compounds, formed of the same elements, in the same relative proportions, and having, therefore, the same composition in 100 parts, are yet entirely distinct from each other in all their properties. Such bodies are called isomeric bodies (from *isos*, equal, and *meros*, part.)

It is obvious that, as the proportions of the elements are the same, the source of the difference in properties must be sought for in the *absolute number*, or in the *arrangement* of the atoms. Thus, acetic ether and aldehyde are two entirely different liquids, containing exactly the same relative proportions of carbon, hydrogen, and oxygen. These proportions, reduced to the smallest number of atoms, are $\text{C}_2 \text{H}_2 \text{O}$. Now, there is no doubt that the absolute numbers in aldehyde are $\text{C}_2 \text{H}_4 \text{O}_2$; and there is also no doubt that the absolute number of equivalents in acetic ether is $\text{C}_4 \text{H}_4 \text{O}_4$. Here it is evident that, although the proportions are the same, the equivalent of acetic ether is twice as large as the equivalent of aldehyde. Again, the composition, in 100 parts, and consequently the relative proportions of the elements, of urea is exactly the same as in hydrated cyanate of ammonia; while the equivalent of both compounds appears to be the same, or, in other words, they contain the same absolute number of atoms of the element. But we know that the hydrated cyanate of ammonia is represented by $\text{NH}_2 + \text{C}_2 \text{NO}, \text{HO}$; and that urea contains neither ammonia NH_3 , nor cyanic acid $\text{C}_2 \text{NO}$. Let us suppose the atoms in urea to be simply united thus, $\text{C}_2 \text{N}_2 \text{H}_4 \text{O}_2$, and we see at once that the same relative and absolute number of atoms may readily give rise to perfectly distinct compounds. In some cases, we know what the arrangement is in both compounds. Thus, hydrated acetic acid, $\text{C}_4 \text{H}_8 \text{O}_6$, $\text{H}_2 \text{O}$, and formiate of oxide of methyle, $\text{C}_2 \text{H}_4 \text{O} + \text{C}_2 \text{H}_2 \text{O}_2$, both contain $\text{C}_4 \text{H}_6 \text{O}_4$. Such isomeric

compounds are called *metameric*; and where the absolute number of atoms differs, *polymeric*; where the absolute number in one or both is unknown, they are called simply *isomeric*.

It is easy to see that, wherever the atoms of the elements of a compound admit of more than one arrangement, metameric compounds may occur. In binary compounds, such as water, H O , there is but one arrangement possible, as long as the absolute number of atoms is not doubled, tripled, or still further multiplied. But in such a compound as peroxide of iron, $\text{Fe}_2 \text{O}_2$, for example, the elements might yield several metameric compounds, such as $2 \text{FeO} + \text{O}$, $\text{FeO} + \text{FeO}_2$, $\text{Fe} + \text{FeO}_2$, not to mention the multitude of compounds which might be formed with precisely the same composition in 100 parts, by increasing the absolute number of atoms.

The discovery of isomerism, however unexpected, is thus entirely consistent with the atomic theory, of which it is merely a special case. Isomerism is of very frequent occurrence among organic compounds, owing, no doubt, to their usually large atomic weights, since the numerous atoms of the elements afford much scope for isomeric modifications; and doubtless this principle plays an important part in the processes of organic life and growth, as well as in decay.

Having premised the preceding general or introductory remarks, we now proceed to the actual description of the elements, and of their compounds, which constitutes Chemistry, properly so-called.

It is not possible, in the present state of our knowledge, to follow any arrangement that shall not be open to objection. The different classes or groups of elements are not so clearly characterized as to permit us to follow a strictly scientific arrangement, and therefore we shall only adhere to the division of the elements into metalloids and metals; and, beginning with the former, describe the elements in the order of their importance and interest. It has already been stated that even this division is not always fully observable, since selenium is classed by some as a metal, and arsenic by others as a metalloid.

METALLOIDS.

There can be no hesitation as to that element which, being the most important of all, ought to be first treated. We therefore proceed to describe —

1. OXYGEN. $\text{O} = 8.013$.

which is of all elements the most abundant; forms 89 p. c. by weight of all the water, and 23 p. c. of the atmospheric air of our globe; exists in all rocks, except rock salt; and is an essential

element in all animal or vegetable bodies. It constitutes at least $\frac{1}{4}$ of the weight of our earth.

Obtained most easily by applying a heat rather below redness to a mixture of chlorate of potash with $\frac{1}{4}$ of its weight of peroxide of manganese. The latter

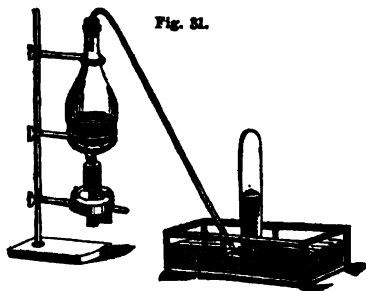


Fig. 51.

undergoes no change, but promotes in a high degree the decomposition of the chlorate. The mixture being introduced into a small retort, or a small flask with a bent tube, may be heated by a spirit lamp, and the gas—which comes off very abundantly and rapidly—collected, over water, in the pneumatic trough. The chemical

change caused in the chlorate by heat is represented as follows :



That is, 1 eq. of the salt yields 1 eq. chloride of potassium, $K\ Cl$, which remains in the retort, and 6 eq. of oxygen, which escapes in the form of gas.

Properties.—A gas, colorless, tasteless, inodorous. Specific gravity (air = 1.000) 1.1026, or, according to Thomson, 1.1111. A burning body, as a match of wood or paper, burns in the gas with greatly increased brilliancy; a spark on a piece of wood bursts out into a flame. Iron wire burns in it, when heated white-hot, with beautiful sparks. Phosphorus burns in it with an intense dazzling white light, &c.

Oxygen combines with all the other elements (except perhaps fluorine), and with most of them in several proportions. The combustion of bodies in oxygen is nothing but their combination with that element; the process, from the energy of the affinities, being attended with heat and light. Thus, when iron burns in oxygen, it yields oxide of iron, $Fe\ O$; and when phosphorus burns in oxygen, it produces phosphoric acid, $P\ O_5$. In all such cases, the oxygen and the combustible body disappear, and a new compound results.

Combustion, or the combination of a combustible with oxygen, goes on in atmospheric air, but much less rapidly and vividly than in pure oxygen, because, in air, the oxygen is diluted with four times its bulk of nitrogen.

Many substances slowly combine with oxygen without the development of heat or light; as, for example, iron, when it rusts.

In every case the combustible is said to be oxidized, or to undergo oxidation, and the compound formed is termed an oxide.

The whole structure of modern Chemistry is founded on the above simple theory of combustion, first proposed by Lavoisier; who, by using the balance, discovered that the burning body became heavier during the process, and could not, therefore, according to the then prevalent theory, have lost phlogiston (an imaginary element), or any thing else.

Lavoisier, having observed that all the acids then known were compounds of oxygen with combustible bodies, concluded that acidity depended on the presence of oxygen, and named that element accordingly (from *oξυς*, acid, and *γεννᾶω*, to produce). The name is still retained, though we are now acquainted with many acids which contain no oxygen; and although, according to views now considered probable, hydrogen has more claim to the title of the producer of acids than oxygen. Besides, oxygen is now known to be an essential ingredient in bases, the basic power of which really seems to be in a close relation to their amount of oxygen. But the inconvenience of changing the name would be very great, so that, while many of the views of Lavoisier have been abandoned, his names are retained.

Lavoisier held that combustion could not take place without the presence of oxygen. But subsequent experience has shown that although all combustions in our atmosphere, or in oxygen gas, depend on the presence of oxygen, the phenomenon of combustion is nothing more or less than chemical combination, attended by heat and light. Many examples might be adduced of combustion without oxygen. Take, for example, the case of iron and sulphur, which, when heated, combine with much heat and light; or that of phosphorus, which, when introduced into chlorine, takes fire and burns, combining with the gas. Although, therefore, oxygen is concerned in all ordinary combustions, that is, in all which take place in our atmosphere, the student must bear in mind the true definition of combustion — namely, “chemical combination, attended with heat and light.”

Oxygen has been termed a supporter of combustion, as distinguished from a combustible body, such as phosphorus. But we are not to suppose that the oxygen has any greater, or any other share in combustion, than the phosphorus. It so happens, that the oxygen is a gas, and the phosphorus a solid. The heat and light, therefore, appear to proceed from the phosphorus; because the combustion can only take place where the two bodies are in contact. But, in reality, both bodies are equally concerned in the production of the heat and light; and while we may call phosphorus a supporter of combustion as well as oxygen, we may call oxygen a combustible as well as phosphorus.

In all combustions in our atmosphere, the heat and light, as above explained, although derived equally from both bodies, or rather from the process of combination, appear to proceed from what is usually called the combustible or burning body. But this is merely appearance: for while a jet of hydrogen, set fire to in a

jar of oxygen, seems to burn and give out the heat and light, a jet of oxygen in a jar of hydrogen may be set fire to, and will then appear, as the hydrogen did before, to be the source of the heat and light, which in both cases was derived from the combination of oxygen with hydrogen.

Oxygen is necessary to the respiration of animals: but for this purpose pure oxygen is not fitted; and it has, therefore, in our atmosphere been diluted with four times its volume of another gas.

When a large quantity of oxygen gas is required, it is generally prepared by heating to redness, in an iron bottle, the peroxide of manganese, of which 88 parts yield 8 of oxygen, according to the equation $2\text{Mn O}_2 = \text{Mn}_2 \text{O}_3 + \text{O}$. Oxygen may also be obtained by the action of heat on nitrate of potash or nitre, on red oxide of mercury, or on red oxide of lead. In practice, the chlorate of potash (of which 124 parts yield 48 of very pure oxygen,) although rather a dear salt, and the peroxide of manganese, which, although not very productive, is very cheap, are alone employed. On the small scale, the peroxide of manganese, heated with sulphuric acid, yields twice as much oxygen as when heated *per se*, according to the equation —



The sulphate of protoxide of manganese, Mn O, SO_3 , remains in the retort. This process is troublesome, and the retort is generally broken during cooling. A better process, lately proposed, is to heat bichromate of potash with an excess of sulphuric acid.

Since oxygen unites with all the other elements, and forms very numerous and important compounds, it may be well here to mention the principal classes of oxidized bodies, or oxides, as the compounds of oxygen are called.

The most numerous class of oxides is that of the basic oxides or bases. These are formed, in every case, by the union of a metal with oxygen. The most frequent formula for a basic oxide is M O (M representing 1 eq. of a metal.) Examples, potash, K O , lime, Ca O , protoxide of iron, Fe O , protoxide of manganese, Mn O . Such bases are called protoxides. Next to these in importance are the sesquioxides, the formula of which is $\text{M}_2 \text{O}_3$. Examples, sesquioxide of iron $\text{Fe}_2 \text{O}_3$, sesquioxide of manganese, $\text{Mn}_2 \text{O}_3$, sesquioxide of antimony, $\text{Sb}_2 \text{O}_3$. Sesquioxides are in all cases weaker bases than the protoxides of the same metals; and, generally speaking, they are found to be weaker bases than protoxides. There are a very few basic oxides of the formula M O_2 . Example, deutoxide or binoxide of tin, Sn O_2 . Finally, there are also a very few basic oxides of the formula $\text{M}_2 \text{O}$. Example, suboxide of copper, $\text{Cu}_2 \text{O}$. Both these last kinds of bases are very feeble, compared to the preceding kinds.

The next important class of oxides is that of the oxygen acids. These are most frequently composed of metalloids united to oxygen; but there are also oxygen acids formed of metals united to oxygen. Examples of the former, carbonic acid C O_2 , sulphuric acid S O_2 , phosphorus acid P O_3 , phosphoric acid P O_5 , nitric acid N O_3 , hyperchloric acid Cl O_7 : of the latter, arsenious acid As O_3 , antimonious acid Sb O_3 , antimonie acid Sb O_5 , chromic acid Cr O_3 , manganic acid Mn O_3 , hypermanganic acid $\text{Mn}_2 \text{O}_7$. It will be observed, that the formula of acids are very various; and it will also be noticed that where a metal forms an acid with oxygen, that acid contains more oxygen than the basic oxide or oxides of the same metal. Thus, sesquioxide of antimony which is basic, is $\text{Sb}_2 \text{O}_3$, while antimony forms two acids, one Sb O_3 , or $\text{Sb}_2 \text{O}_5$, and the other $\text{Sb}_2 \text{O}_7$.

The third class of oxides is that of the neutral or indifferent oxides. These are neither decidedly acid, nor decidedly basic, and some of them play both parts; on the one hand combining with bases, as a weak acid would do; on the other, uniting with acids like a weak base. This is the case with water H O , which, itself neutral, combines both with acids and bases, forming compounds which are still acid or basic, and are called hydrates. Examples, H O , S O_3 , oil of vitriol, or hydrated sulphuric acid; K O , H O , caustic potash, or hydrate of potash. Others do not enter into any combination, but are strictly indifferent; such as deutoxide of hydrogen, H O_2 , and deutoxide (binoxide, peroxide, or superoxide) of manganese. Where, as in this last example, the metal also forms a basic oxide or oxides, and an acid or acids, it is important to notice, that the indifferent oxide is intermediate in composition, as if a certain proportion of oxygen communicated basic properties, a somewhat larger proportion destroyed these without producing acidity, and a still larger share of oxygen gave to the compound distinctly acid characters. By inspecting the compounds of manganese with oxygen, we further see that of the two basic oxides, both of which contain less oxygen than the indifferent oxide, or superoxide, that which contains the most oxygen is the weaker base.

Mn O	Protoxide of manganese.	A powerful base.
$\text{Mn}_2 \text{O}_3$	Sesquioxide of do.	A feeble base.
Mn O_3	Superoxide of do.	Neither basic nor acid.
Mn O_5	Manganic acid.	A strong acid.
$\text{Mn}_2 \text{O}_7$	Hypermanganic acid.	A strong acid.

When the superoxide, or indifferent oxide of a metal, is acted on by an acid, it loses oxygen, while a basic oxide, being left, combines with the acid; as in the process for obtaining oxygen by the action of sulphuric acid on peroxide of manganese, given and explained at p. 66.

Oxygen was discovered by Priestley, in 1774; and in the following year by the Swedish chemist, Scheele, without any knowledge

of Priestley's discovery. The time, in fact, had come when chemistry was studied in the true scientific spirit; and had these illustrious men not then discovered oxygen, it must, nevertheless, have been very soon discovered by some one else.

2. HYDROGEN. $H = 1$.

Occurs in nature only in combination, chiefly in the form of water, of which it constitutes 11 per cent. by weight. It is an essential ingredient in all organized bodies.

It may be easily prepared by causing diluted sulphuric or hydrochloric acid to act on iron filings, or on granulated zinc. The best apparatus for the purpose is a wide-mouthed bottle, furnished with a closely-fitting cork. In this cork are made two holes, into one of which a tube properly bent is closely fitted, while into the other is inserted, also air-tight, a straight tube, reaching to the bottom of the bottle, and widened at its upper end, so as to form a funnel. Both tubes are open at both ends, and the bent tube terminates, within the bottle, just below the cork, while its further end dips under water in the pneumatic trough.

The metal being introduced into the bottle, and covered to the depth of an inch with water, the cork with the tubes is fitted in: the acid is poured in through the straight tube, and the bottle shaken, so as to mix the acid and water thoroughly. Enough of acid should be added to cause a brisk, but not violent effervescence; and as the end of the straight tube is covered by the liquid, the gas produced can only escape through the bent tube. Care must be taken not to collect the gas for use until the whole of the air originally in the upper part of the bottle has been expelled; otherwise the application of a light might cause a dangerous explosion. Perhaps the safest way is to collect, in a large jar full of water, as much of the gas which first escapes as would suffice to fill the gas-bottle twice, and to throw this away: what comes subsequently is pure. When the current of gas slackens, the addition of a little more acid, through the straight tube, causes it again to go on as briskly as at first.

When zinc and hydrochloric acid are employed, the process is represented by the following equation: $Zn + HCl = H + ZnCl$. That is, the zinc takes the chlorine of the acid, forming chloride of zinc, and the hydrogen is separated. When iron and sulphuric acid are used, the process is expressed by the equation $Fe + HO, SO_3 = H + FeO, SO_3$. Here the hydrogen is supposed to proceed from water, the oxygen of which forms, with the iron, protoxide of iron, which again unites with the sulphuric acid,



forming sulphate of protoxide of iron. It is to be observed, that this, the generally received explanation of the latter process, is very different from that of the former, although the phenomena in both are the same, namely, the escape of hydrogen and the formation of a neutral salt. When treating of acids and salts, we shall see how it is possible to do away with this complexity, and to bring both processes under one formula.*

(The above simple method of obtaining hydrogen gas is equally applicable in all cases where a gas is to be produced by the action of an acid on a solid body, without the aid of heat; as in the cases of deutoxide of nitrogen, sulphuretted hydrogen, carbonic acid, &c. It has, therefore, been described minutely, and will hereafter be referred to in describing the preparation of the above gases.)

Properties.—Hydrogen is a gas, colorless, tasteless, and, when quite pure, devoid of smell. When prepared from common zinc or iron, it contains some foreign body, which gives it an unpleasant smell. It is the lightest body known, its Sp. G. being 0.0694 (air = 1), or 16 times less than that of oxygen. A lighted candle, introduced into hydrogen, is extinguished, but the hydrogen takes fire at the mouth of the vessel, where it is in contact with the oxygen of the air, and burns rapidly away, giving out but little light, with an intense heat, and producing water, which, by proper means, may be condensed and collected. Hydrogen gas is not absorbed by water.

Hydrogen does not combine so readily with other bodies as oxygen does. It may be made, however, to combine with most of the metalloids and with a few of the metals. With chlorine, bromine, iodine, and fluorine, it forms powerful acids, the general formula of which is HR ;† with carbon, sulphur, phosphorus, selenium, tellurium, and arsenic, it forms combustible gases, several of which have acid properties. With nitrogen, it forms ammonia, NH_3 , and probably two other compounds, ammonium, NH_4 , and amidogen, NH_2 .

From its extreme lightness, 100 cubic inches weighing only about 2.5 grs., while common air is about 14 times heavier, hydrogen is used for filling balloons.

* I do not suppose that hydrogen is derived from the deoxidation of water, but that it is more likely obtained from the acidifying hydrogen of the sulphuric acid. For instance, this acid in its active state, is $SO_4 + H$. In the action which takes place, the hydrogen of the acid is simply displaced by an equivalent of zinc, and the gas is liberated; therefore the amount of gas which we obtain does not depend upon the quantity of water which we add, so much as that of sulphuric acid, as it would be impossible to get more than the one equivalent of hydrogen which is combined with the acid. The reason for adding the water, is to dissolve the sulphate of zinc, which adheres to the metal and would prevent further action, sulphate of zinc, it will be recollected, being insoluble in strong sulphuric acid. S

† R here stands for 1 eq. of any of the metalloids just mentioned.

Besides the processes above described, hydrogen is obtained by passing the vapor of water (steam) over red-hot iron wire, when the iron is oxidized at the expense of the water; also by placing potassium or sodium in water, when these metals are instantly oxidized: and by heating to redness a mixture of potash, or soda, and organic matter, such as sugar, saw-dust, &c.

HYDROGEN AND OXYGEN.

a. Water. $\text{HO} = 9.013$.

Hydrogen may readily be made to unite with oxygen, whether pure or in the form of atmospheric air. When hydrogen is mixed with oxygen or with air, the mixture takes fire and explodes violently on the approach of a flame, or when the electric spark is passed through it. A jet of hydrogen, issuing from a tube, may be set fire to by the same means; and in both cases water is the only product.

We have already seen that 1 grain of hydrogen combines with 8 of oxygen to form water; and as no other element takes up so large a proportion of oxygen, this is probably the reason why the combination of hydrogen with oxygen is attended with so intense a heat.

If hydrogen and oxygen be mixed in the exact proportion of 2 vol. of the former to 1 vol. of the latter, and the mixture set fire to, as it issues from a small tube, the most intense heat is produced that it is possible to obtain by combustion. The flame of

the oxy-hydrogen blowpipe, as it is called, readily melts platinum and pipe-clay, substances which resist the fire of the hottest furnaces. By this means, Mr. A. Kemp has melted 6 oz. of platinum at once.*

The gases, if previously mixed, should be made to pass through a safety-apparatus before being set fire to; but as accidents have occurred even when the safety-apparatus was used, it is, in all cases, better to keep the gases in separate gas-holders, and to allow them to mix only in the tube, just before they are

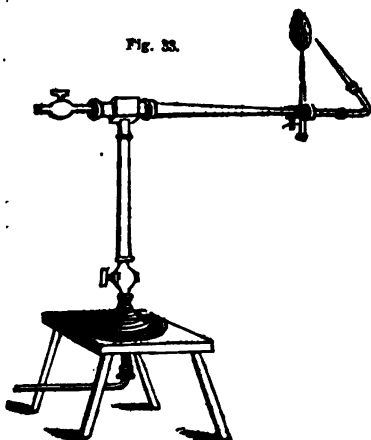


Fig. 33.

* Dr. Hare, of Philadelphia, has melted twenty-three ounces of platinum at once, by means of a blowpipe of his own contrivance. B.

ignited, regulating the flow of the two gases so as to obtain the most intense heat. Any excess of either gas cools the flame and diminishes the effect. For the jet best adapted to this experiment, see the cut.*

When a portion of spongy platinum, or of the finely-divided black powder of that metal, is introduced into a mixture of hydrogen with oxygen, or with air, the platinum soon becomes red-hot, and then the explosion instantly follows. Or if a jet of hydrogen be thrown on the metal in the air, it becomes red-hot and ignites the jet. On this principle is constituted the beautiful instantaneous light apparatus of Döbereiner.

It would appear that the platinum possesses the property of causing hydrogen and oxygen to combine on its surface, whereby heat is developed sufficient to make the metal red-hot; and it then acts as any other red-hot body, such as flame, would do, in causing an explosion.

The observations of Döbereiner on the properties of the black powder of platinum may assist us to explain this singular property of platinum. He found that the powder condensed within its pores 253 times its volume of oxygen, and as the pores occupy only $\frac{1}{4}$ of the bulk of the powder, this oxygen must be in a state of condensation such that it occupies only $\frac{1}{1012}$ of its volume in the form of gas. In this state it must be denser than water, and we may easily conceive how it is thus rendered capable of at once combining with hydrogen. Spongy platinum only differs from the powder in being less minutely divided.

If a jet of hydrogen be set fire to and a cold dry bell jar held over the flame, the inside of the jar will instantly be covered with a film of dew which rapidly increases, and at last condenses into drops of water. This water, if collected, is found to be quite pure; and if a known weight of hydrogen be burned, and the whole water collected without loss, the weight of the water will be nine times that of the hydrogen: the difference, or 8 parts in 9 of water, is oxygen.

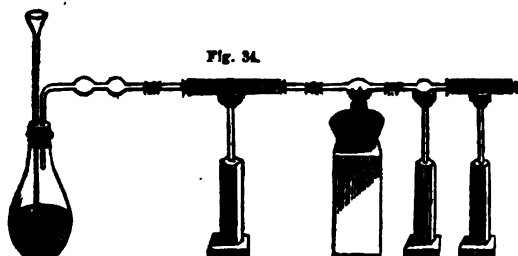
This most important point—namely, the true composition of water—may be ascertained in other ways. Thus, if 2 vols. of pure hydrogen and 1 vol. of pure oxygen be mixed and confined over water or mercury, and if the electric spark be passed through the mixture, both gases will entirely disappear, and water alone will be the product. If the experiment be made in a graduated tube, and if, for example, 210 vols. of hydrogen be mixed with

* It is almost unnecessary to remind the reader, that Dr. Hare, of Philadelphia, is the inventor of the oxy-hydrogen blowpipe. It was used by this illustrious chemist several months before he made it public, and it was not till some time after the appearance of his paper upon this subject, that it was noticed at all in Europe. Still an attempt has been made to deprive Dr. Hare of his discovery. S.

100 vols. of oxygen, and the mixture exploded, 10 vols. of hydrogen will remain unchanged ; or if the proportions had been 200 vols. of hydrogen to 110 of oxygen, 10 of oxygen would have been left. Now as hydrogen is 16 times lighter than an equal bulk of oxygen, it follows that 2 vols. of hydrogen must be 8 times lighter than 1 vol. of oxygen ; and thus we arrive at the same result as to weights as we obtain by burning hydrogen and weighing the water produced.

Another, and a very beautiful method of ascertaining the composition of water, by weight, is the following :

Into the bulb blown in the middle of a wide tube of Bohemian glass, the weight of which is known, there is introduced a weighed portion of oxide of copper. One end of the tube is then connected with an apparatus, from which a steady current of dry hydrogen is disengaged ; and to the other end is attached a tube containing fragments of chloride of calcium, a substance possessing a strong attraction for water ; this tube with its contents being also weighed.



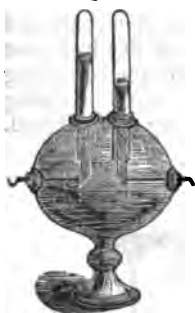
As soon as the whole of the atmospheric air of the apparatus has been entirely displaced by the hydrogen gas, heat is applied, by means of a spirit lamp, to the oxide of copper. Aided by the high temperature, the hydrogen very soon begins to decompose the oxide of copper, combining with its oxygen to form water ; and before long the black color of the oxide is changed to the red of metallic copper. The water which is formed condenses in the cold part of the tube beyond the bulb ; but by heating that part of the tube the whole of the water is soon carried by the current of gas into the tube with chloride of calcium, where it is retained. The apparatus is now allowed to cool, and when the tubes have again become full of atmospheric air, they are weighed. That with the copper will be found lighter than before ; the other, heavier. The loss of the former is oxygen ; the increase of the latter is the water which that oxygen has yielded ; and, of course, the difference between the two is the hydrogen of the water.

Let us suppose the first tube, when empty, to have weighed 500 grains, and when filled with the oxide of copper 540 grains, the

oxide of copper must weigh 40 grains. The tube with chloride of calcium weighs, before the experiment, say 300 grs. Now, we should find, after the experiment, that the first tube now containing metallic copper, would weigh 632 grs., and the other tube 309 grs.; the former having lost 8 grs. (oxygen), while the latter has gained 9 grs. (water). Hence the 9 grs. of water contain 8 of oxygen, and, of course, 1 gr. of hydrogen. Moreover, this experiment tells us that 40 grs. of oxide of copper are composed of 32 of copper and 8 of oxygen; thus proving the composition of water by synthesis, and that of oxide of copper by analysis.

There is still another method of demonstrating the composition of water — namely, the decomposition of that

Fig. 35.



fluid by galvanic electricity. When the electric current of a powerful battery is made to pass through water, in an apparatus so contrived that the gas given off at each pole may be received into a separate graduated tube, it is found that by the time the tube at the positive pole is half full, the tube at the negative pole is quite full; and on examination the gas in the latter is found to be pure hydrogen, while that in the former is pure oxygen; and the proportion, by volume, is obviously 2 of hydrogen to 1 of oxygen, and from this, by means of the specific gravities of the gases, we obtain, as before, the proportion,

by weight, of 1 to 8.

Water, which is thus proved to contain 1 eq. of hydrogen to 1 eq. of oxygen, represented by H O , is, at ordinary temperatures, a liquid, colorless, tasteless, and inodorous. It assumes the solid form, that of *ice* or *snow*, at 32° F., and all lower temperatures; and it takes the form of gas or vapor, that of *steam*, at 212° F., and retains that form at all higher temperatures. When ice is heated above 32° , it melts into water; and when steam is cooled below 212° , it condenses into water. Thus water possesses the liquid form only at temperatures lying between 32° and 212° .

Hence, in certain arctic regions, water is always, or nearly always, solid. Even in that state, however, and at all temperatures below 212° , it is always slowly assuming the gaseous form. It is in this way that watery vapor is constantly rising into the atmosphere from the surface of the sea, of lakes, of rivers, and of the soil; which watery vapor, being again condensed into the liquid form, falls back on the earth in the shape of rain or dew, or, if frozen, as snow, hail, and hoar-frost.

Water is perfectly neutral; that is, it exhibits in itself neither acid nor basic properties: but is capable of combining with both acids and bases, and, indeed, seems to be almost essential to their activity. The compounds of water with acids and bases are called

hydrates; as H_2O , SO_3 , hydrated sulphuric acid, and K_2O , H_2O , hydrate of potash.

Water combines also with neutral salts, and that in two conditions. In one it is easily expelled by heat, and the salt, if crystallized, generally falls to powder when the water has been expelled. This is called water of crystallization, and its quantity is often very large. In the other, a portion of water, generally 1 eq., is combined with the salt by so powerful an affinity that it is with some difficulty separated. This is called saline water, because it may be replaced by an equivalent of a neutral salt. In formula, water of crystallization is represented by aq. (for aqua), and saline water by H_2O . Thus, green vitriol is represented by FeO , SO_3 + H_2O + 6 aq.; that is, 1 eq. of neutral sulphate of protoxide of iron, 1 eq. of saline water, and 6 eq. of water of crystallization. When this salt is gently heated, the 6 eq. of water of crystallization are expelled, but the 1 eq. of saline water can only be expelled by a red heat. It can also be replaced by a neutral sulphate, such as sulphate of potash, K_2O , SO_3 , and the resulting double salt is FeO , SO_3 + K_2O , SO_3 + 6 aq. Here, as in the green vitriol, the 6 eq. of water of crystallization are easily expelled by a gentle heat.

In relation to acids, therefore, water acts the part of a base; in relation to bases, that of an acid; and in relation to neutral salts, that of a neutral or indifferent substance, or, indeed, of a neutral salt. Taking the three examples of hydrated sulphuric acid, H_2O , SO_3 , hydrate of potash, K_2O , H_2O , and dry sulphate of iron, FeO , SO_3 + H_2O , it is to be observed that the water in the first can only be replaced by a base, such as potash, K_2O , which would yield sulphate of potash, K_2O , SO_3 ; the water in the second can only be replaced by an acid, such as sulphuric acid, SO_3 , which would yield the same salt, K_2O , SO_3 ; and the water in the third may be replaced by a neutral salt, such as sulphate of potash, K_2O , SO_3 , which would give rise to the double salt, FeO , SO_3 + K_2O , SO_3 . Water in these three different characters is called basic water, hydratic water, and saline water, and, in addition to these, we have water of crystallization.

Besides these numerous forms of combination, in which water most frequently loses the liquid form, it enters, as a liquid, into a peculiar kind of combination with the greater number of all known substances: it dissolves them. Of all liquids, water is the most powerful and general solvent, and on this important property its use depends. By the solvent power of water, substances, inert in the solid form, are made to assume the liquid form, and thus to become active—chemical action is promoted—substances mixed together may be separated from one another;—in short, without water, not only the operations of the chemist, but the processes of animal and vegetable life, would come to a stand.

The solvent power of water, in regard to solid bodies, is generally increased by heat.* Hot water, therefore, dissolves more of most bodies than cold water does; so that when a hot saturated solution cools, it deposits a quantity of the dissolved solid, commonly in crystals.

Water readily dissolves or combines with, or absorbs, as it is termed, many gaseous bodies. The gas, in this case, assumes the liquid form; and as heat tends to cause bodies to assume the gaseous form, it is obvious that heat must diminish, and cold increase, the solvent power of water for gases. Increased pressure also enables water to absorb more of a gas than it will do under the ordinary pressure, evidently because pressure favors the liquefaction of a gas, by forcing the particles nearer to each other.

In consequence of the great solvent power of water, it is never found pure in nature. Even in rain water, which is the purest, there are always traces of carbonic acid, ammonia, and sea-salt. When the rain water has filtered through rocks and soils, and reappears as spring or river water, it is always more or less charged with salts derived from the earth, such as sea-salt, gypsum, and chalk. When the proportion of these is small, the water is called soft; when larger, it is called hard water. The former dissolves soap better, and is therefore preferred for washing; the latter is often pleasanter to drink, as its saline contents communicate to it a slight, but agreeable taste.

When water becomes so highly charged with foreign matters as to have an unpleasant taste, or to acquire medicinal virtues, it is called mineral water. Of mineral waters there are several kinds: those in which iron predominates are called chalybeate waters; where sulphur prevails, they are called sulphurous waters; acidulous waters are those which contain much free carbonic acid; and saline waters are such as contain neutral salts, generally sea-salt, and sulphate of magnesia, or Epsom salt.

The only way to obtain perfectly pure water, is to distil it; and in the laboratory, no water except distilled water should ever be used, provided distilled water can be procured in sufficient quantity.

Water is the standard of specific gravity for liquid and solid bodies, and its specific gravity is therefore represented by 1.

* According to Wiltstein, one part, by weight, of lime dissolves in 729-733 parts of water, at ordinary temperatures, and in 1810-1850 parts of boiling water. The deposit which settles down when lime-water is exposed to the air consists of Ca O , C O_2 . The *Milk of Lime* and *Cream of Lime* are mere mixtures of hydrate of lime and water of different degrees of thickness.—8.

b. Deutoxide of Hydrogen. $\text{HO}_2 = 17.013$.

This compound is formed, in some cases, where oxygen is presented in the nascent state to water. The best process is that of Pelouze, which consists in adding to diluted hydrofluoric acid (fluosilicic or phosphoric acids may equally be used), kept very cold, exactly so much of the peroxide of barium, that neither barium nor the acid can be detected in the liquid, the whole of both being precipitated as fluoride of barium: $\text{BaO}_2 + \text{HF} = \text{BaF} + \text{HO}_2$. The deutoxide of hydrogen is dissolved by the surrounding water, and the filtered liquid is concentrated by being placed under the exhausted receiver, along with a vessel containing sulphuric acid, the whole being kept cold. The process, even in this form, is tedious and difficult, but much less so than the original method of Thénard, who discovered the compound.

The deutoxide, peroxide, or superoxide of hydrogen, when as free from water as possible, is a syrupy liquid, colorless, and possessed of a slight disagreeable odor, like that of bleaching liquor, and of a peculiar nauseous, bitter, and astringent taste. Its Sp. G. is 1.453 (water = 1). It does not become solid, even in a very intense cold.

This compound is very easily decomposed, yielding water and oxygen. The contact of carbon, of many metals, and even of metallic oxides, also of many salts, causes the separation of oxygen, often with explosion, and sometimes with a flash of light. It is very remarkable that peroxide of manganese, for example, should cause this rapid decomposition, without combining with any part of the disengaged oxygen; and still more astonishing, that oxide of silver should decompose it with explosion, while the oxide of silver, so far from combining with more oxygen, loses all that it previously contained, and is reduced to the metallic state. We cannot, at present, explain these phenomena. The application of heat to the deutoxide of hydrogen, causes oxygen to escape with effervescence. It is less easily decomposed when diluted, and especially if acidulated; the presence of a base, on the contrary, hastens its decomposition.

It is very probable that this remarkable compound will be found to possess valuable properties as a medicinal agent, and it is much to be desired that its preparation could be rendered easier.

3. NITROGEN. $\text{N} = 14.19$.

Syn. Azote. — Discovered by Rutherford, in 1772. Occurs principally in the atmosphere, of which it forms 79 or 80 parts in 100 by volume, and about 77 by weight; also, in minute quantity, in the atmosphere as ammonia. It is an essential ingredient of all animal tissues, and of all such vegetable products as can be converted into blood in the animal body; also of the vegetable bases and other vegetable compounds, such as indigo, &c. &c.

It is best obtained by the action of burning phosphorus on a confined portion of air, over water. The phosphorus takes the oxygen, forming phosphoric acid, which is soon removed by the water, and nitrogen gas is left.

Fig. 24.



Nitrogen is a colorless and transparent gas, devoid of taste and smell, and chiefly distinguished by the absence of active properties. It does not support combustion, neither does it burn itself. It is incapable of supporting animal life, and consequently an animal, immersed in pure nitrogen, soon dies; but only because oxygen is absent, for nitrogen itself is so far from being poisonous, that the air we breathe contains $\frac{1}{4}$ of its bulk of that gas in an uncombined state. It serves to dilute the oxygen, and for that purpose it is admirably adapted, from the absence of marked characters or strong affinities. Its specific gravity is rather less than that of air, being 0.976.

Nitrogen cannot be made to unite directly with any element, and only forms combinations when one or both elements are in the nascent state. It is, therefore, unlike the other metalloids, in a high degree chemically indifferent or neutral. But, under favorable circumstances, it does combine with most of the metalloids, and with several metals. Its most important compounds are those with oxygen and with hydrogen. Almost all compounds of nitrogen are easily decomposed, and many of them are even dangerous, from their tendency to explode from very slight causes.

It is this very character of easy decomposability that gives to the compounds of nitrogen their very high importance in the organized kingdoms of nature. We shall hereafter see how important a part these compounds perform in the formation, as well as in the destruction, of organic bodies.

NITROGEN AND OXYGEN.

a. Atmospheric Air.

The air of our atmosphere is formed of nitrogen and oxygen, not in a state of combination, but simply mixed together. Dalton has shown that, when any two gases, however different in density, are placed in communication, they are very soon found to be completely and equally mixed, even although they have no tendency to combine chemically. This is the case with the gases in air. The properties of each are present, only modified slightly by the presence of the other; whereas chemical combination gives rise to new compounds, possessing entirely new properties. This is eminently the case in the compounds which are really formed between nitrogen and oxygen, so that we are forced to look upon the air as a mixture merely.

It is remarkable, however, that the proportions of the gases are such as correspond almost exactly, by weight and by volume, to 2 eq. nitrogen and 1 eq. oxygen. Of 100 vol. of air, 79 or 80 are nitrogen, and 20 or 21 oxygen. Here we have the ratio of 4 vol. to 1. 100 parts of air, by weight, contain nearly 77 of nitrogen and 23 of oxygen; that is almost exactly 28 of nitrogen to 8 of oxygen, or N_2O .

The physical properties of air are well known. It is, like all gases, elastic, and it possesses such a density, that 100 cubic inches weigh about 31 grs. Hence, the whole atmosphere presses on the surface of the earth with a very great force, equal to about 14 lbs. on each square inch of surface. In other words, a column of air, 1 square inch in base, and equal in height to the atmosphere, weighs 14 lbs. But the further consideration of this subject belongs to physics. Air is made the standard of specific gravity for gases and vapors, and its Sp. G. is made 1.000.

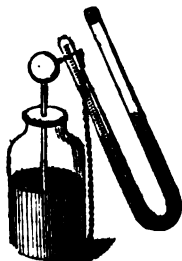
The chemical properties of air are chiefly those of the oxygen it contains, modified by the presence of 4 times its bulk of the negative body, nitrogen. Air supports combustion, and the respiration of animals, as long as the proportion of oxygen does not fall below a certain amount.

Besides nitrogen and oxygen, the air always contains more or less watery vapor, which is almost equally important to animal and vegetable life, since neither animals nor plants can live long in a perfectly dry air.

Air also contains, as ingredients essential to the life of plants, and thus indirectly also to that of animals, minute proportions of carbonic acid and of ammonia. The amount of the former seldom, in the open air, exceeds $\frac{1}{1000}$ part of the weight of the air; while the proportion of ammonia is much smaller even than this.

When it is required to ascertain the exact proportion of oxygen in any specimen of air, the object may be obtained in a variety of ways. The operation is called eudiometry, and the instruments employed eudiometers. The most commonly employed is that of Volta, modified by Ure, which is simply a graduated glass tube,

Fig. 37.



closed at one end, bent as in the figure, and furnished with two platinum wires, to allow the electric spark to pass. The air being introduced and measured, half its bulk of pure hydrogen gas, or thereabouts, is added, and the whole measured again. The gas being confined by water or mercury, and the open end of the tube stopped by the finger or thumb, the spark is passed through the mixture, when an explosion takes place, and a certain portion of the mixture disappears, the water or mercury rising in the tube to supply its place. The residue is now

measured, and $\frac{1}{2}$ of the volume which has disappeared is oxygen. It is obvious that, if there be enough of hydrogen, the whole of the oxygen will assume the form of water, and both the oxygen and hydrogen of that water must lose the gaseous form. Now as water is formed of 2 vol. hydrogen to 1 vol. oxygen, $\frac{1}{2}$ of the volume of the gases which have combined must be oxygen.

If, for example, 100 measures of air are mixed with 50 of hydrogen, the bulk of the whole will be 150. If, now, after explosion, 87 parts remain, it is plain that 63 have disappeared, and of these 63 measures 21, or $\frac{1}{3}$, are oxygen, originally contained in the 100 of air, while 42, or $\frac{2}{3}$, are hydrogen.

Gay-Lussac has lately proposed to remove the oxygen from a measured portion of air, by means of copper moistened by sulphuric or hydrochloric acid, which soon absorbs that gas completely. The diminution of volume here is exactly equal to the proportion of oxygen present.

There are many other eudiometrical methods, but the above are the best.

The amount of water in the atmosphere is ascertained by hygrometers, of which there are various kinds. That of Daniell is the best. It is founded on the fact, that the temperature at which the water contained in the air is deposited as moisture, varies with the amount of moisture present. The drier the air, the more must it be cooled before it begins to deposit moisture. If the air be saturated with moisture, the cooling of it one degree will cause a deposition of dew, and the temperature at which dew is deposited, is called the dew-point. The details of this and other hygrometers belong to physics.

The presence of water in the atmosphere may be shown at any time by exposing a deliquescent substance, such as chloride of calcium, to the air, when it quickly becomes moist, and finally liquefies by attracting moisture. Air, or any other gas, may thus be dried, either in a tube over mercury, into which the drying substance is introduced, or by passing the gas through a long tube filled with the substance in coarse powder, or through strong sulphuric acid, which has a powerful affinity for water.

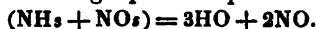
The uses of atmospheric air are obvious. Besides supporting animal and vegetable life, it is essential to all our modes of obtaining heat and light by combustion.

It is very important to remark, that although the processes of respiration and combustion, as well as that of the decay and putrefaction of animal and vegetable matter, are constantly removing oxygen from the air, yet the proportion of that element never diminishes, being kept up by the process of vegetable life. In like manner, respiration and combustion are continually sending carbonic acid into the atmosphere in place of the oxygen they consume, and yet the air does not become more highly charged

with carbonic acid; for the same process of vegetable life which restores oxygen to the air, removes an equal bulk of carbonic acid, — from which, indeed, the oxygen thus restored is derived.

b. Protoxide of Nitrogen. $\text{NO} = 22.203$.

Syn. Nitrous Oxide; Intoxicating or Laughing Gas. — Prepared by applying a moderate heat to pure nitrate of ammonia in a retort. The salt melts, boils, and is soon entirely volatilized in the form of water, which trickles down the neck of the retort, and protoxide of nitrogen, which being gaseous, may be collected over water. The following equation represents the change:



Showing that 1 eq. of ammonia and 1 eq. of nitric acid yield 3 eq. water, and 2 eq. protoxide of nitrogen.

This compound is a gas, colorless and transparent. It has a faint smell and a sweetish taste. It is slowly absorbed by water, and therefore cannot be long kept over that liquid. Its specific gravity is 1.527. It may be liquefied by a pressure of 50 atmospheres.*

By weight it contains 8 parts of oxygen to 14 of nitrogen, and by volume, 2 vol. of nitrogen and 1 vol. of oxygen, condensed into the bulk of 2 vol. Hence this gas contains its own bulk of nitrogen, and half its bulk of oxygen, while air only contains $\frac{1}{4}$ of its bulk of that gas. Consequently, as some combustible bodies, such as phosphorus, or a candle, if burning, are capable of decomposing this gas and seizing its oxygen, they burn in it with great brilliancy. Probably for a similar reason, it is capable of supporting life for a short time, if respired, and its action on the human system is most remarkable. In most persons it causes very agreeable sensations, a sense of lightness, a rapid and brilliant flow of ideas, accompanied with an irresistible tendency to laughter and to very violent muscular exertion. These effects only last for a minute or two after the gas has been breathed as long as possible: but they are not followed, like those of other excitants, by any sense of depression or languor; on the contrary, a certain feeling of exhilaration and unusual lightness of spirits is often felt for a whole day after. In some cases the effects are unpleasant, such as headache, a rush of blood to the head, and a tendency to stupor. The experiment must be therefore made with caution, and the gas withdrawn, should the face of the experimenter appear flushed to any considerable extent. As he is often,

* Liquid Protoxide of Nitrogen is a clear, colorless, very mobile liquid. If a drop of it touches the skin, it produces instant disorganization, resembling that of a burn. Metals dropped into it hiss like red hot iron. Mercury is instantly frozen, as also are sulphuric and nitric acids. Ether and alcohol are not frozen, but water is instantly frozen, producing by the sudden evaporation of the liquid, a kind of explosion. Ignited charcoal floats in it burning with great brilliancy. S.

however, unwilling to relinquish the bag of gas, an aperture should be made in the side of the breathing-pipe, and stopped with a cork, which may be removed if necessary, thus admitting air to the mouth, and putting an end to all danger. These very singular properties of this gas were first discovered by Davy; and in a physiological point of view, they merit further investigation than they have yet received. The gas has been tried in medicine, but hitherto without much benefit; although in America it is said to have been found useful in cases of melancholia.

Protoxide of nitrogen is neutral or indifferent, and has hardly any tendency to combine with other bodies. According to Pelouze, however, it combines with the salts of sulphurous acid, or sulphites.

c. Deutoxide of Nitrogen. $\text{NO}_2 = 30.216$.

SYN. Nitric Oxide: Nitrous Gas.—Best obtained by the action of copper clippings on moderately strong nitric acid, in the apparatus, p. 63. The metal is dissolved with effervescence, and the gas may be collected and preserved over water.

A gas, transparent and colorless. Its taste and smell are not known, because as soon as it comes in contact with air, it forms, with the oxygen, red vapors of nitrous acid, which have a suffocating smell and a rough acid, corrosive taste. It supports, like the preceding gas, the combustion of burning phosphorus, and for the same reason, namely, that it contains half its bulk of oxygen, being formed of equal volumes of nitrogen and oxygen, united without condensation. Its specific gravity is consequently the mean between those of oxygen and nitrogen, or 1.0416. A burning candle is extinguished in this gas, and it not only does not support life, but cannot be breathed, as it forms nitrous acid gas in the mouth, and the glottis instinctively closes against the latter.

Its most distinctive character is that of forming, when mixed with air or oxygen, a red gas or vapor, which is nitrous acid, and which instantly disappears if in contact with water, being absorbed by that liquid. As the formula of the deutoxide is NO_2 , and that of nitrous acid NO_3 , it is plain that the latter may be formed from the former by the mere addition of oxygen. As the red vapors are very remarkable, the deutoxide may be used as a test of the presence of free oxygen in a gaseous mixture.

If a few drops of bisulphide of carbon be added to a jar of this gas, and a light applied to the mixture, it burns rapidly with a bright blue flash of light.

The deutoxide of nitrogen is abundantly absorbed by any solution containing a salt of protoxide of iron, such as green vitriol, forming a brown solution, from which the gas may be expelled unchanged by boiling. This solution absorbs oxygen, and has been used in eudiometry, but it does not give accurate results.

d. Hyponitrous Acid. $\text{N O}_2 = 38.229$.

SYN. Acide Nitreux; Salpetrige Sâûre.—It is formed when a strong base, such as potash, is brought into contact with the preceding gas, protoxide of nitrogen being given off, while the acid unites with the base. Thus :



It is best obtained, however, by heating one part of starch in 8 parts of nitric acid, Sp. G. 1.25, and conducting the disengaged gases, first through a long tube filled with chloride of calcium, to remove water, and then through a dry tube cooled down to -4° F. in which latter the acid condenses, as a very volatile liquid which, while cold, is colorless, but at the ordinary temperature becomes green. Its properties are little known.

In contact with water it is destroyed, giving rise to nitric acid and deutoxide of nitrogen, thus :



The salts of this acid are obtained by heating a nitrate,—for example, nitrate of potash or soda,—till it begins to precipitate nitrate of silver brown. The whole is then precipitated by nitrate of silver, the precipitate dissolved in boiling water, and the hyponitrite of silver crystallizes on cooling. From this salt, by the action of soluble chlorides, the other hyponitrites may be obtained. They have been little studied.

e. Nitrous Acid. $\text{N O}_2 = 46.242$.

SYN. Acide Hyponitrique. Untersalpetersâûre.—This is the acid which appears as red vapors when deutoxide of nitrogen mixes with air, or with oxygen. 1 vol. deutoxide of nitrogen, and $\frac{1}{2}$ vol. of oxygen, if mixed quite dry, and cooled, form the liquid nitrous acid; but it is most easily obtained by distilling dry nitrate of lead. Equation,



In this experiment oxide of lead is left, and oxygen gas and nitrous acid pass over, the latter condensing in the well-cooled receiver. If intensely cold, it is colorless; but as it becomes warmer, it assumes a yellow or orange color. Its Sp. G. in the liquid form is 1.42. It boils at about 82° , and is converted into a deep red vapor, or gas, which, if further heated, becomes nearly black, or impervious to light. If once mixed with air or any other gas, it can only with very great difficulty be condensed, so that it is commonly seen in the form of vapor. It has an unpleasant suffocating smell, and cannot be breathed with impunity even for a moment. It supports the combustion of almost all combustible bodies, by virtue of its large proportion of oxygen.

In contact with water, it is destroyed, giving rise, like the preceding acid, to nitric acid, and deutoxide of nitrogen. Thus, $3 \text{NO}_2 = 2 \text{NO}_3 + \text{N}_2\text{O}$. As it undergoes the same change in contact with all bases hitherto tried, its salts are unknown. Along with pure nitric acid, it forms the orange-fuming nitric acid of the shops, often called nitrous acid.

f. Nitric Acid. $\text{NO}_3 = 54.255$.

Formula of the hydrated acid, $\text{H}_2\text{O}, \text{NO}_3$, or $\text{H}, \text{NO}_3 = 63.268$.

This, the most important of all the compounds of nitrogen and oxygen, occurs very frequently in nature, chiefly combined with potash or soda, forming nitre and cubic nitre; also in minute proportion in rain water after thunder-storms. It is formed in natural or artificial nitre beds, where animal or vegetable matter containing nitrogen is exposed to the air along with bases. The nitrogen being disengaged as ammonia, NH_3 , is oxidized along with the hydrogen, yielding nitric acid and water; thus $\text{NH}_3 + \text{O}_2 = \text{NO}_3 + 3 \text{H}_2\text{O}$. The acid is seized by the base present, and nitre is formed. The nitric acid occasionally found in rain water is also produced by the oxidation of ammonia; its quantity is too small to arise from the oxidation of the nitrogen of the air. The dry acid, NO_3 , is unknown in the separate form;* if we attempt to separate it from water or a base, it is resolved into nitrous acid and oxygen; thus, $\text{NO}_3 = \text{NO}_2 + \text{O}$.

The hydrated acid, $\text{H}_2\text{O}, \text{NO}_3$, or H, NO_3 , is the substance commonly called nitric acid. It is best prepared by the distillation of a mixture of equal weights of hydrated sulphuric acid, or oil of vitriol, and of nitre or saltpetre, the nitrate of potash. The salt in coarse powder being introduced into a plain retort, the acid is poured in by means of a retort funnel. The retort is then placed in a sand-bath over the lamp, and cautiously heated, till the acid begins to drop into the receiver, which is to be surrounded with cold water. As the nitre generally contains a little sea-salt, the first portions of acid which distil are impure, containing chlorine, and nitrous acid; but they serve to wash quite clean the neck of the retort; on which some sulphuric acid is commonly to be found, in spite of all our care, as well as traces of the powdered nitre.

* Since the above was written, *M. Deville* has succeeded in producing what he deems this acid. Perfectly dry chlorine, is passed over dry nitrate of silver. If the nitrate is heated to 203°F . and then reduced to $140^\circ - 150^\circ$, the decomposition proceeds regularly. Hyponitrous acid is at first formed, but as the temperature is reduced, the anhydrous nitric acid is deposited in crystals in the cold parts of the apparatus, which is cooled with ice. Anhydrous nitric acid forms large, brilliant, colorless crystals in six-sided prisms of the trimetric system. May melt at 85° , and boil at 113° . Much heat is evolved when they are brought in contact with water, and solution ensues without escape of gas. This solution forms nitrates. S.

It is best, therefore, to collect the first portion, say $\frac{1}{3}$ of the whole, in a separate receiver, and when the liquid that drops is found to

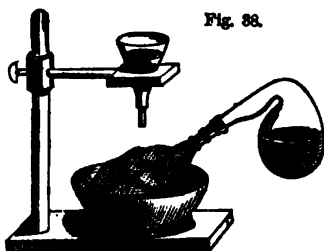
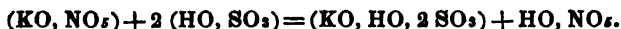


Fig. 38.

be free from chlorine (by the test of nitrate of silver), the receiver is changed, and the rest of the nitric acid is thus obtained quite pure, or at most, slightly tinged by nitrous acid. By this simple device, we avoid the necessity of redistilling the acid, as commonly directed. The impure portion which first passes over, is extremely well adapted for all experiments of illustration,

and ought to be carefully preserved for such purposes.

The following equation explains the change in this process:



For 1 eq. of nitre, we take 2 eq. of oil of vitriol, and we obtain 1 eq. of hydrated bisulphate of potash, and 1 eq. of hydrated nitric acid. We take equal weights of the materials, because 1 eq. of nitre weighs 102, while 2 eq. of oil of vitriol weigh 98; and a slight excess of the latter is advantageous rather than otherwise. By using 1 eq. of oil of vitriol, we may also obtain nitric acid; but a much higher temperature is required, and a large part of the acid is decomposed into oxygen, which escapes, and nitrous acid, which combines with the nitric acid, giving it a deep red color, and causing it to give out red fumes. Moreover, in the latter case, neutral sulphate of potash is left, which can hardly be got out of the retort without breaking it; while the bisulphate of potash, formed in the operation first described, may be easily dissolved out by hot water.

Hydrated nitric acid, when pure, is a colorless liquid, giving out dense gray fumes, on exposure to the air. Its Sp. G. is 1.52 to 1.53. It freezes at 40°, and boils at 108°. If diluted somewhat with water, so as to have the Sp. G. 1.42, it boils at 248°; but if still weaker, it boils more easily, and become stronger, till the boiling point reaches 248°, when it distils over unchanged. Nitric acid has a pungent, rather disagreeable smell, is very acid and corrosive, and stains the skin, and organic matter in general, yellow.

It has a strong attraction for water, and becomes hot when mixed with it. (Acid of middling strength, mixed with snow, causes it to liquefy instantly, producing intense cold.)

Nitric acid is very easily decomposed. If passed through a red-hot porcelain tube, it is resolved into oxygen and nitrogen. All combustible or oxidizable bodies deprive it of oxygen, redu-

cing it to nitrous acid, hyponitrous acid, or deutoxide of nitrogen; and even, in some cases, removing all the oxygen, and leaving only nitrogen gas. The action is generally attended with heat; and in some cases, such as phosphorus and essential oils, combustion takes place, and even dangerous consequences may ensue from the acid, or the burning body; which is scattered about by the violent commotion. Nitric acid is, therefore, a very powerful oxidizing agent, and is much used for oxidizing and dissolving metals, such as silver, copper, mercury, &c. It is remarkable that the very strongest acid does not attack metals; but, on the addition of a few drops of water, a most violent action ensues.

The presence of nitric acid in a liquid is best ascertained by adding pure oil of vitriol, and then a drop or two of solution of green vitriol. If nitric acid be present, a red or brown color will appear where the two liquids meet; and by this test N^{O}_3 of nitric acid may be detected.

Pure nitric acid ought to be entirely volatile; and when diluted with distilled water, to give no precipitate with the salts of baryta, or of silver.

Nitric acid is used in medicine, and in the arts; in the latter, as aquafortis. To the chemist, it is one of the most valuable agents, and is daily employed as a means of oxidizing metals and organic substances. The tendency of this acid to yield oxygen to combustible bodies is found also in its salts, especially at a red-heat; and hence, nitrate of potash, or saltpetre, is an essential ingredient of gunpowder, and of the various mixtures used for rockets and fire-works; in all of which it is mixed with charcoal and sulphur.

With bases, nitric acid forms salts called nitrates. Most of these are neutral, with the general formula MO, NO_3 ; but there are a few basic nitrates, in which one or more atoms of the base are added to the neutral salts. All the nitrates are decomposed by sulphuric acid, and they may be recognized by deflagrating with red-hot charcoal, and by the test above given for nitric acid, which distinguishes them from other deflagrating salts, such as chlorates, &c.

NITROGEN AND HYDROGEN.

a. Amide. $\text{NH}_3 = 16.19$.

Syn. Amidogen.—This compound is unknown in a separate state, but is believed, with good reason, to exist in many compounds. If potassium, for example, be heated in dry ammoniacal gas, NH_3 , $\frac{1}{3}$ of the hydrogen is expelled, and an olive-colored solid remains, the composition of which is K, NH_2 . It is viewed as a compound of potassium with amide, the amide or amiduret of potassium. When put into water, potash and ammonia are formed, thus: $\text{K}, \text{NH}_2 + \text{HO} = \text{KO} + \text{NH}_3$. Compounds of amide with sodium, with carbonic oxide (oxamide), with benzoyls

(benzamide), and other substances, are known. Their general character is, in contact with water, and under the influence of acids and bases, to be resolved into ammonia and an oxidized product commonly an acid. Thus oxamide, $C_2 O_2, NH_2$, along with water, HO , in the presence of an acid or alkali, yields ammonia, NH_3 , and oxalic acid, $C_2 O_3$. It is this very powerful affinity for hydrogen which has hitherto defeated all our efforts to isolate amide. The various compounds of amide will be described in their proper order.

b. Ammonia. $NH_3 = 17.19$.

Syn. Volatile alkali—Occurs in combination with hydrochloric acid, as sal ammoniac; in the urine of animals, especially of birds and reptiles, as urate of ammonia; in several aluminous and ferruginous rocks and earths in small quantity; finally, in the air, as a constant result of the putrefaction, decay, or combustion of organic matters containing nitrogen.

It is formed abundantly in putrid urine (from urea), and in the destructive distillation of organic nitrogenized matter, as, in Egypt, by heating camel's dung; in Europe, formerly, by distilling horn, hence the name spirit of hartshorn; at present, by distilling any animal refuse; or in the distillation of coal in gas-works, which yield abundance of ammonia. In all these cases it is found as carbonate.

To obtain ammonia, powdered sal ammoniac is mixed with about an equal weight of dry hydrate of lime (slacked lime), and
 Fig. 39. the mixture heated in a retort, or a flask fitted with a bent tube. The ammoniacal gas is abundantly disengaged, and may be collected over mercury, or, as it is much lighter than air, by displacement, the tube being made to reach, as in the cut, to the closed end of the gas-receiver, the open end being downward. A large tube or vessel may be easily filled with the gas in this way, and preserved by immersing the open end, when filled, in a small cup of mercury. The following equation represents the change in its production. $(NH_3, HCl) + (CaO, H O) = CaCl + 2H O + NH_3$.



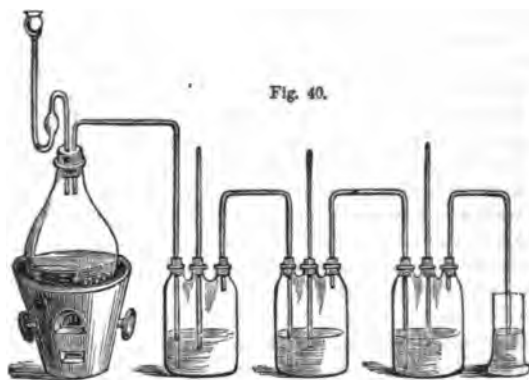
Ammonia is a gas, transparent and colorless, of a very pungent and peculiar smell and taste. It is liquefied by a pressure of about five atmospheres. It is instantly absorbed by water, forming the solution of the gas called aqua or liquor ammoniæ. It extinguishes a candle, does not burn itself under ordinary circumstances, and if respired undiluted, is fatal to animal life. Its Sp. G. is 0.5902, being thus little more than one-half as heavy as air. It possesses strongly alkaline or basic properties, neutralizing the strongest acids. The approach of any gaseous or volatile acid, such as carbonic, hydrochloric, or nitric acids, to the mouth of a

jar of ammonia, causes the formation of dense white clouds of carbonate, hydrochlorate, or nitrate of ammonia. By this property and by its smell, it is easily detected and recognized.

Ammonia is formed by the union of 3 vol. hydrogen and 1 vol. nitrogen, which yield not 4 vol. but 2 vol. ammoniacal gas. Here condensation to one-half has taken place.

AQUA AMMONIÆ, OR LIQUOR AMMONIÆ.

This most useful re-agent is best prepared by causing the gas disengaged from the above mixture of sal ammoniac and slacked lime by heat, a little water having been previously added to moisten the powder, to pass through cold water in an apparatus, furnished with a safety-tube, to prevent undue absorption, the gas being washed by means of a very little water placed in an intermediate bottle. The water, if kept cold, will absorb about 670 times its bulk of the gas, by which it is increased in bulk, acquires a Sp. G. of only 0.872, and becomes possessed of all the chemical properties of the gas in a very high degree. This is the aqua ammoniæ fortissima of the manufacturers, and for medical use it requires to be diluted till it has the Sp. G. of 0.96. At 0.872, it becomes 32.5 per cent. of dry gas; at 0.96, hardly 10 per cent. Hence, by adding 8 vol. of water to 3 vol. of the strongest ammonia, we reduce it to the ordinary medical strength, which is also sufficiently strong for the usual chemical purposes.



This solution is constantly employed by the chemist for neutralizing acids, and precipitating insoluble bases. It has the very great advantage of not introducing any fixed matter, so that the re-agent may be totally expelled by a red-heat. In medicine it is much employed, internally, as a diffusible stimulant, and externally as a powerful rubefacient, and also along with oil as a

counter-irritant. If it can be procured in time, it is the best antidote to prussic acid.

With acids, ammonia forms salts, which are recognized by their yielding the pungent smell of ammonia when mixed with caustic potash or slacked lime. They are either volatile in the fire, as carbonate, sulphate, &c.; or they are decomposed, the ammonia being driven off and the acid remaining behind as phosphate of ammonia. For the constitution of the salts of ammonia, see below.

c. Ammonium. $\text{NH}_4 = 18.19$.

This compound, like amide, is not known in the separate state; but we have reason to believe that it exists, and has the chemical relations of a metal: hence its name.

When a salt of ammonia is decomposed by galvanic electricity, the negative pole terminating in a drop of mercury, the mercury swells to many times its original bulk, becomes almost solid, but retains its metallic aspect. The same compound is formed when an amalgam of mercury with potassium or sodium is placed in aqua ammoniæ, or in contact with a moistened ammoniacal salt. It is crystalline, and has been regarded as an amalgam of mercury and ammonium. When removed from the pole, and placed in water, it gives off ammonia and hydrogen, and the mercury resumes its original bulk. The remarkable circumstance is, that the amalgam contains so small a weight of ammonium (or of ammonia + hydrogen), although its properties are so different from those of the mercury. But, if we suppose an amalgam to be formed of 10 eq. of mercury and 1 eq. ammonium, this would contain less than 2 per cent. of the latter. There is, therefore, nothing unreasonable or very improbable, in the idea of a compound metal ammonium, NH_4 . Indeed, if we assume its existence, we are enabled to take a view of the constitution of the salts of ammonia, which makes them analogous to those of the other alcalies.

It was formerly the universal opinion that ammonia, NH_3 , combined directly with oxygen acids, such as sulphuric acid, SO_3 , as well as with hydrogen acids, such as hydrochloric acid, HCl .

According to our present knowledge, the hydrochlorate of ammoniades really contain the elements $\text{NH}_3 + \text{HCl}$, although we may suppose them otherwise arranged: but it has been shown that sulphuric acid, SO_3 , although it can be made to unite with ammonia, does not produce sulphate of ammonia; but that the formation of this latter salt requires, besides the elements of ammonia and sulphuric acid, those of 1 eq. of water, H_2O ; and that the salts of ammonia, with the oxygen acids in general, contain, as an essential ingredient, this 1 eq. of water. It is not easy to see why

ammonia should form neutral salts without the aid of water, when acted on by hydrogen acids, and should require water when combining with oxygen acids. But if we admit that ammonium exists, and is the true basic radical in all these salts, the whole becomes clear. In that case, $\text{NH}_3 + \text{H}_2\text{O}$, ammonia + 1 eq. of water, becomes NH_4 , O, or oxide of ammonium; sulphate of ammonia + water ($\text{NH}_3, \text{H}_2\text{O} + \text{SO}_3$) becomes dry sulphate of oxide of ammonium, NH_4 , O, SO_3 ; and hydrochlorate of ammonia, NH_3, HCl , becomes chloride of ammonium, NH_4 , Cl. It has been observed, that the oxygen acid salts of ammonia + water are isomorphous with the dry salts of potash. Now, on the old view, we can trace no analogy between $\text{NH}_3, \text{H}_2\text{O}, \text{SO}_3$, and KO, SO_3 ; but, if we admit the existence of the metal ammonium, and, still more, if we represent it by the symbol Am, the analogy becomes obvious. Thus we have the two series:

	Potassium.	Ammonium.	Do. at full length.
Metal . . .	K . . .	Am . . .	NH_4
Oxide . . .	KO . . .	Am O . . .	NH_4 , O
Chloride . .	KCl . . .	Am Cl . . .	NH_4 , Cl
Sulphate . .	KO, SO_3	$\text{Am O}, \text{SO}_3$	NH_4 , O + SO_3 .

The only difference between the two series is, that we know Am to be a compound, while K is, as yet, undecomposed. But, as formerly remarked, all our present elements may hereafter prove to be compounds; and even were this not so, we can easily conceive a compound metal playing the same part as a simple one.

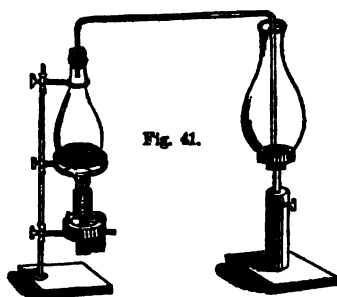
We have to bear in mind that ammonium, if it exists, is resolved into ammonia NH_3 and hydrogen, whenever we attempt to isolate it: that ammonia, in combining with a hydrated oxygen acid, such as $\text{H}_2\text{O}, \text{SO}_3$, takes the hydrogen of the water, forming ammonium NH_4 , which, with the oxygen of the water, produces oxide of ammonium, and that the oxide then unites with the acid: and, finally, that ammonia, in contact with a hydrogen acid, such as HCl , takes the hydrogen of the acid to form ammonium, which then unites with the acid radical chlorine. Indeed, this very simple view may be extended to the hydrated oxygen acids, if we view them as hydrogen acids. Hydrated sulphuric acid, $\text{H}_2\text{O}, \text{SO}_3$, may be viewed as a hydrogen acid, H, SO_4 : and if ammonia act on this, we have either $\text{NH}_3 + \text{H}_2\text{O}, \text{SO}_3 = \text{NH}_4, \text{O}, \text{SO}_3$, or $\text{NH}_3 + \text{H}, \text{SO}_4 = \text{NH}_4, \text{SO}_4$; the latter being perfectly analogous to the formation of chloride of ammonium (sal ammoniac), $\text{NH}_3 + \text{HCl} = \text{NH}_4, \text{Cl}$.

The above is a sketch of the ammonium theory of Berzelius, which is beautifully consistent, if we once admit the existence of ammonium: rendered, as it is, so probable by the phenomena of the amalgam, and by the isomorphism of the compounds of potash and those of ammonia + 1 eq. water. This theory is pretty generally adopted by chemists.

4. CHLORINE. $\text{Cl} = 35.47$.

This element occurs in prodigious quantity in the well known substance, sea or rock salt, in which it is combined with sodium. It is also occasionally found in combination with lead, silver, and mercury. Chloride of potassium is a frequent ingredient of ashes, especially of the ashes of sea-plants.

It is best prepared by the action of peroxide of manganese on hydrochloric acid. 1 part of finely-powdered peroxide is covered in a roomy flask with 6 parts of moderately strong hydrochloric acid (4 parts of concentrated acid and 2 of water); to the flask is



fitted tightly a tube bent twice at right angles, the longer limb of which is conducted to the bottom of a dry, wide-mouthed bottle, furnished with a tight glass stopper. The chlorine, on the application of a gentle warmth, escapes in the form of gas, and being much heavier than air, is very easily collected in dry vessels by displacement. As soon as the bottle is filled, which is easily seen from the yellow color

of the gas, it is withdrawn and replaced by another. If the gas is to be kept, the stopper must be tightly fitted into the bottle, and the juncture well greased.

The following equation shows the change: $\text{MnO}_2 + 2\text{HCl} = \text{MnCl} + 2\text{HO} + \text{Cl}$. Here one-half of the chlorine is given off as gas, while the other remains behind as chloride of manganese.

Chlorine, at the usual temperature, is a gas which is liquefied by a pressure of about four atmospheres. It is transparent and of a strong yellowish-green color: hence its name. Its Sp. G. is 2.500. Its smell is very disagreeable, pungent and suffocating; when much diluted, it recalls the smell of the air on the sea-shore. If respired pure, it causes instant death; and even when diluted with air, excites cough, pain, and a sense of stricture on the chest, often lasting for many hours, and only relieved by a very copious expectoration of thick mucus, but occasionally followed by spitting of blood. The irritation thus caused may often give rise to permanent and serious disease of the lungs, and, therefore, care should be taken not to breathe the gas in working with it. It is not a little remarkable, however, that, if very much diluted, although still apt to excite cough, it is found to alleviate the symptoms of phthisis when inhaled, probably by promoting expectoration. The patients themselves soon learn to bear it stronger, and to long for the hour of inhaling it. It is also stated that the workers in manufactories of bleaching powder, and in bleaching

and dye-works, where the air is always to some extent charged with chlorine, are less liable to phthisis than others; so that, up to a certain point, the system seems capable of becoming habituated to it with benefit.

Chlorine supports the combustion of many substances, such as a candle; many take fire spontaneously in it, as phosphorus, antimony, oil of turpentine, &c. It may be made to burn itself in an atmosphere of hydrogen gas, or coal gas.

Chlorine gas dissolves in water: hence it cannot be preserved over that liquid. The solution is termed chlorine water. It has the smell of the gas, and bleaches vegetable colors most powerfully, which perfectly dry chlorine does not. It also destroys foetid or noxious effluvia, and is very useful in checking the spread of contagious disease.

The affinities of chlorine for the metals are very powerful, frequently stronger than those of oxygen. It therefore decomposes many oxides, as well as bromides, iodides, sulphides, &c., at ordinary temperatures, and almost all the rest at a red-heat. It acts so strongly on mercury that it cannot be collected over that metal. But its strongest affinity is to hydrogen, with which it forms hydrochloric acid. It is to this powerful affinity that the bleaching properties of chlorine are to be ascribed; it seizes on part of the hydrogen of the coloring matter, and thus decomposes it entirely. The same remark applies to the destruction of effluvia and miasmata.

The presence of free chlorine is detected by its smell and its power of bleaching solution of indigo. Nitrate of silver also causes with it a curdy white precipitate of chloride of silver, insoluble in acids. (See Hydrochloric Acid.)

The compounds of chlorine, which are not acids, are called chlorides.

SOLUTION OF CHLORINE.

This solution is prepared by simply passing a slow current of chlorine gas through water (previously boiled and allowed to cool), placed in inverted retorts nearly full. As soon as water begins to escape at the neck of one retort, the tube is transferred to another, and so on alternately till the water refuses to absorb any more. The solution, which has the color, smell, and bleaching properties of the gas, must be kept in small bottles, quite filled, and closely fitted with glass stoppers. A drachm or more of this, added to about four or six ounces of water at 100°, forms a mixture through which air may be drawn into the lungs when we wish diluted chlorine to be inhaled. The solution is decomposed by light, and ought, therefore, to be kept in the dark.

Chlorine combines both with oxygen and hydrogen; but as the compound of chlorine with hydrogen is the most important, we shall here deviate slightly from the natural order, and treat of it first.

CHLORINE AND HYDROGEN.

Hydrochloric Acid. $\text{H Cl} = 36.47$.

SYN. *Muriatic Acid*—Is formed when equal volumes of chlorine and hydrogen are mixed and exposed to light, flame, or the electric spark, all of which cause the gases to combine with explosion. Is best prepared by the action of sulphuric acid on sea-salt, when the gas is disengaged even without the action of heat. As water instantly absorbs it, it must be collected over mercury, or by displacement, as it is somewhat heavier than air.

The following equation shows the formation of the acid: $\text{Na Cl} + (\text{H O, S O}_2) = \text{H Cl} + (\text{Na O, S O}_2)$; or, $\text{Na Cl} + \text{H, S O}_4 = \text{H Cl} + \text{Na, S O}_4$.

Hydrochloric acid is a gas, transparent and colorless, fuming strongly with moist air, of a pungent, acid, suffocating smell, and a strong sour taste. Its Sp. G. is the mean between those of chlorine and hydrogen, or 1.284, it being formed of equal volumes of these gases without condensation. It is absorbed in large proportion by water, forming the common or liquid hydrochloric acid, which is merely a solution of the gas in water. This solution reddens, but does not bleach, vegetable blue colors; and neutralizes the alkalies, yielding neutral salts, which are found to be chlorides.

When it acts on soda, Na O , for example, we obtain neutral crystals by evaporation; but these are found to be sea-salt, Na Cl , and contain neither oxygen nor hydrogen, so that these latter elements must have united to form water; thus: $\text{Na O} + \text{H Cl} = \text{Na Cl} + \text{H O}$. The result is, in regard to neutrality, the same as if the acid and alkali had directly combined together and neutralized each other: for the chloride of sodium (Na Cl) and water are both neutral. The general formula for the action of this and similar hydrogen acids on metallic oxides, is as follows: $\text{H R} + \text{M O} = \text{M R} + \text{H O}$. Here R stands for chlorine, or any other acid radical and M for any metal. If the oxide be a sesquioxide, the formula will be $3 \text{H R} + \text{M}_2 \text{O}_3 = \text{M}_2 \text{R}_3 + 3 \text{H O}$. Here, 3 eq. hydrogen acid and 1 eq. sesquioxide yield 1 eq. sesquichloride (bromide, iodide, &c.) and 3 eq. water; but the principle is the same. In some cases, however, hydrochloric acid appears to combine with oxides; as with alumina or oxide of chromium.

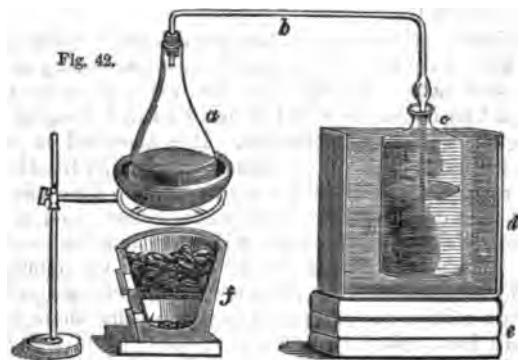
It will be easily seen, from what has just been said, that the action of hydrochloric acid on oxides affords a ready and convenient means of obtaining the corresponding chlorides. This method is very often employed.

HYDROCHLORIC ACID AND WATER.

LIQUID, OR AQUEOUS HYDROCHLORIC ACID.

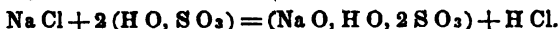
SYN. *Liquid Muriatic Acid: Spirit of Salt*.—This most indispensable re-agent is best prepared by the following easy process,

which moreover yields it perfectly pure; 6 parts, by weight, of pure salt are introduced into a flask or matrass, and covered with 10 parts, by weight, of oil of vitriol, and 4 parts of water, the latter having been previously mixed, and the mixture allowed to cool; or we may take 8.5 parts, by measure, of sulphuric acid, Sp. G. 1.68. No action takes place in the cold, so that we may adapt securely a bent tube to convey the gas to the flask. This tube is twice bent at right angles, and has a bulb blown on the longer descending limb. In a bottle, surrounded with ice-cold water, is placed a quantity of distilled water equal in weight to the salt, and the bent tube is made to dip about $\frac{1}{4}$ inch into this water. A gentle heat is



now applied to the flask, which rests in a sand-pot, and continued as long as any hydrochloric acid comes over. In about two hours the process is finished, and we find the distilled water increased in volume nearly two-thirds, and converted into hydrochloric acid, quite pure and colorless, of Sp. G. 1.14 to 1.15. If we wish it as strong as possible, or of Sp. G. 1.21, we have only to employ, in a second operation, a part of the acid above described in the place of the distilled water, during the first half of the operation, when it will speedily become saturated. No safety-tube is required: it is only necessary to lower the bottle a little occasionally, so that the tube shall never dip far into the liquid; and even should absorption take place too rapidly, and the water rise in the tube, the bulb will receive it, the end of the tube will be exposed, and air entering will prevent the regurgitation of the water into the flask. This simple tube, therefore, forms a self-acting valve, and renders a safety-tube unnecessary. The absorbing liquid must be kept as cold as possible, by frequently changing the surrounding water, which becomes warm owing to the heat developed in the absorption. If ice can be had, a little added to the cooling-vessel, from time to time, keeps the temperature sufficiently low.

In the above operation, the proportions of acid and salt are according to the formula,



Here, 2 eq. of acid are employed for one of salt; for two reasons. First, a much lower heat is required; and secondly, the resulting salt, bisulphate of soda, is quite easily got out, without risking the flask, which is not the case when 1 eq. of acid is used, and neutral sulphate is left. The acid is diluted to Sp. G. 1·65, or even 1·60, for the same reasons. The addition of the water facilitates the operation, and renders the resulting mass more soluble and manageable. It is to be observed that, notwithstanding this addition of water, $\frac{3}{4}$ of the hydrochloric acid gas comes off quite dry, and it is only toward the end of the operation that, the heat being increased, water and acid come off together. This is easily known by the tube becoming hot from the condensation of the steam. From first to last, not a trace of sulphuric acid passes over, even into the tube; and thus by using tolerably pure materials, we obtain colorless and pure hydrochloric acid, as easily and cheaply as if we were making the very impure acid of commerce. By the above process, the purest and strongest hydrochloric acid might be sold for not more than 3*d.* per lb., probably for less.

Pure aqueous hydrochloric acid has, when concentrated, a Sp. G. of 1·21, and fumes strongly when exposed to the air, the gas constantly escaping and uniting with the vapor which it meets. The acid even fumes when no denser than 1·13, and acid of from 1·14 to 1·16 is most convenient for common use, as there is not so much gas lost from it as from the strongest. It ought to be quite colorless: if yellow, it contains perchloride of iron or free chlorine, probably both. The liquid is very acid and corrosive. When a rod dipped in aqua ammonia is brought near, very thick white fumes of sal ammoniac are formed. If heated, gas is expelled, the boiling point, which is at first very low, gradually rising, till the Sp. G. falls to 1·100, when the boiling point is rather higher than that of water; and at this strength the acid distils over unchanged. A weaker acid, if boiled, loses water, and becomes stronger; while a stronger, as we have seen, loses gas, and becomes weaker. We can, therefore, purify the common acid by diluting it to Sp. G. 1·100, and distilling it, rejecting the first and last portions. The intermediate portion is pure, but cannot in this way be obtained concentrated.

The presence of hydrochloric acid is detected by nitrate of silver, which forms, even in very diluted solutions, a white curdy precipitate of chloride of silver, insoluble in acids. It is to be borne in mind, however, that the presence of free chlorine and soluble chlorides give rise to the same compound: we must, therefore,

ascertain their absence, and the presence of an acid, before we can rely on this test.

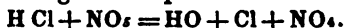
The muriatic acid of commerce is very impure. It contains fixed impurities, detected by evaporation to dryness; sulphuric acid, detected by adding to the liquid, first distilled water, and then a salt of barium; chloride of iron, detected by ferrocyanide of potassium; free chlorine, recognized by its power of dissolving gold; and sulphurous acid, easily known by its smell. It often also contains tin and arsenic, which may be discovered by the proper tests of those metals. As no re-agent is so much employed by the chemist, and none so necessary to have perfectly pure, the chemist ought never, in careful experiments, to use the common acid: and it is on this account that I have so minutely described the method which I have given for obtaining it pure, and which is now generally adopted in the Continental laboratories.

Hydrochloric acid is much used in chemical investigations, chiefly for dissolving inorganic bases, with most of which it forms soluble chlorides: the exceptions are oxide of silver and protoxide of mercury, the chlorides corresponding to which are insoluble; and protoxide of lead, which yields a sparingly soluble chloride. In all inorganic researches, and above all, in the analysis of minerals, soils, &c., it is absolutely indispensable.

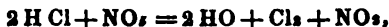
Hydrochloric acid may be viewed as the type of all acids, including the so-called hydrated oxygen acids. We shall have occasion to return to this subject when treating of the acids of sulphur, and also in the general remarks on salts.

NITRO-MURIATIC, OR NITRO-HYDROCHLORIC ACID.

Syn. Aqua Regia.—This, which was formerly viewed as a distinct acid, and celebrated for its power of dissolving gold, is in reality a mixture. It is made by adding nitric acid to twice or thrice its bulk of strong hydrochloric acid. Both acids are decomposed, according to the equation:



Here the products are water, chlorine, and nitrous acid. It is also possible that the change may be as follows:



where the products are water, chlorine, and hyponitrous acid. While neither nitric, nor hydrochloric acid, if pure, can dissolve gold or platinum separately, this mixture does so readily. It is certain, that free chlorine can dissolve those metals, and that their solution in aqua regia yields chlorides on evaporation; but there is reason also to believe, that the nitrous, or hyponitrous acids, contribute powerfully to the solvent power of the aqua regia, possibly by yielding oxygen to the metals, as these acids are more easily decomposed than nitric acid.

CHLORINE AND OXYGEN.

The affinity of chlorine for oxygen is very feeble, and these elements cannot be made to combine directly. By indirect means, however, they may be made to unite, and four compounds are known, all of which are acids.

a. Hypochlorous Acid. $\text{Cl O} = 43.483$.

SYN. *Acide Hypochloreux. Unterchlorige Säure.*—When chlorine gas is passed through a cold diluted solution of an alkali, compounds are formed, which are known as bleaching compounds, and have been considered to consist of chlorine and metallic oxides, such as the so-called chlorides of lime and soda. They are however, in reality mixtures of chloride of the metal with hypochlorite of the oxide. Thus 2 eq. soda and 2 eq. chlorine, instead of combining together, act on each other as follows:—



The true bleaching compound of soda contains, therefore, 1 eq. of chloride of sodium + 1 eq. hypochlorite of soda.

To obtain hypochlorous acid in the free state, red oxide of mercury and water are agitated with chlorine; when there are formed a compound of perchloride and peroxide of mercury, which is insoluble, and hypochlorous acid, which dissolves in the water.



By rectification, a stronger solution may be obtained; and if this be placed in a retort with an excess of dry nitrate of lime, this salt seizes on the water, and the hypochlorous acid gas separates, and may be collected over a saturated solution of nitrate of lime.

It is a gas of a strong yellow color, and a peculiar penetrating smell. It is very easily decomposed into two vol. chlorine, and 1 vol. oxygen, exploding by the mere contact of many combustible substances, or by a gentle heat. Experiments with it require the greatest caution.

Water absorbs about 100 times its volume of this gas, and acquires a pale yellow color, and the astringent, not acid, taste and peculiar smell of the gas. It bleaches powerfully, and is easily decomposed by all substances which have a strong affinity for chlorine or for oxygen.

With the stronger bases it unites, forming salts which are called hypochlorites, the general formula of which is M O, Cl O . With acids, these salts yield hypochlorous acid, not chlorine; and they are thus distinguished from the true bleaching salts, which, when acted on by acids, yield pure chlorine. The bleaching salts have

the general formula $M Cl + M O, Cl O$; that is, as already stated, they are mixtures or compounds of chlorides and hypochlorites. The action of sulphuric acid on them is as follows:



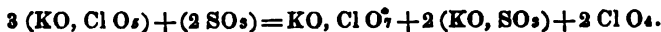
Here all the chlorine, both that of the chloride, and that of the hypochlorite, is given off in the free state. Hence, as chlorine is the real bleaching agent, the great bleaching power of the chlorides of lime and soda, as they are called. The action of dilute sulphuric acid on bleaching powder (chloride of lime or $Ca Cl + Ca O, Cl O$), furnishes a very easy and economical method of disengaging rapidly a large quantity of chlorine gas, as in fumigating a large room or house; no heat is required; we have only from time to time to add a table spoonful of bleaching powder to a basin of diluted acid.

When boiled, the hypochlorites as well as the bleaching compounds, which consist of hypochlorite + chloride, are resolved into chlorides and chlorates. Thus 3 eq. hypochlorite of potash $3 (KO, Cl O)$ yield 1 eq. chlorate of potash, $KO, Cl O_3$, and 2 eq. chloride of potassium, $2 K Cl$. Of course, if, as in the bleaching compound of potash, the 3 eq. of hypochlorite were mixed with 3 eq. of chloride, the result would be 1 eq. of chlorate, and 5 eq. of chloride.

b. Chlorous Acid. $Cl O_2 = 67.522$.

SYN. Peroxide of Chlorine. Chlorige Salire. Acide Hypochlorique. — This acid is obtained by mixing oil of vitriol very gradually and cautiously with chlorate of potash, and applying to the yellow pasty mass thus formed, in a retort placed in a bath of proof spirit, a very gentle heat. Chlorous acid is given off as a deep yellow gas, which is even more easily decomposed, and more explosive than the preceding acid. Hence, very great caution, and the use of a glass mask, are necessary in experimenting with it. It may be collected over mercury. Its smell is peculiar, almost aromatic. It is absorbed by water, which acquires its odor and its bleaching properties.

The following equation explains its formation:



That is, 3 eq. chlorate of potash, and 2 eq. sulphuric acid, yield 1 eq. perchlorate of potash, 2 eq. sulphate of potash, and 2 eq. chlorous acid.

The compounds of chlorous acids with bases are not much known. In contact with alcalies, chlorous acid appears to be resolved into chloric and hypochlorous acids. Thus, $4 Cl O_2 = 3 Cl O_3 + Cl O$.

c. Chloric Acid. $\text{Cl O}_3 = 75.535$.

Syn. Hyperoxymuriatic Acid. — This acid is formed, as we have seen, in combination with a base, under different circumstances; as, when the solution of a hypochlorite is boiled; when chlorine is passed through a hot and strong solution of an alkali; and when chlorous acid is brought in contact with bases. It is evident that in the second case a hypochlorite is formed, but is by the heat as rapidly destroyed, yielding a chlorite (see chlorate of potash); and if we suppose 6 eq. of potash to be acted on by 6 eq. chlorine, we may suppose the first stage to be represented as follows:



And in the second stage, the 3 K Cl remaining unchanged, we have,

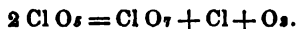


Or, omitting the first stage, as temporary only in the heat, we have,



To obtain chloric acid, chlorate of baryta is dissolved in water, and sulphuric acid is added, so as exactly to precipitate all the baryta as sulphate. The clear solution is concentrated by spontaneous evaporation.

When very strong, it forms a yellowish oily-looking liquid, very sour to the taste. A piece of paper dipped in it, soon takes fire, from the ease with which the acid yields its oxygen. It is resolved by distillation into hyperchloric acid, oxygen, and chlorine.



The salts of this acid, which are called chlorates, are quite permanent, but readily explode with combustible matter at a red-heat; or, in some cases, by friction and percussion alone, or by contact of oil of vitriol. Thus phosphorus and charcoal explode most violently in contact with chlorate of potash — the latter by friction, the former by percussion: and a kind of instantaneous light, formerly much used, consisted of a mixture of chlorate of potash, sugar, and a little gum, to make it adhere, placed on the end of a match, and dipped into oil of vitriol, when it took fire. The lucifers now used are also made with the same salt, and take fire by friction. (See chlorate of potash.)

d. Perchloric Acid. $\text{Cl O}_7 = 91.561$.

Syn. Hyperchloric Acid. — This acid may be obtained either by the distillation of chloric acid (see above), or by the distillation of hyperchlorate of potash with an equal weight of oil of vitriol,

previously mixed with half as much water. It is purified from sulphuric acid by means of baryta, from chlorine by oxide of silver; and is then concentrated by slow evaporation.

It resembles the preceding acid, and when very concentrated, has a Sp. G. of 1.65. It reddens litmus without bleaching it, boils at 412° , and may be distilled without change. It is very permanent, and has strong affinities. Its best known salt is the perchlorate of potash, which is so sparingly soluble, that the acid may be used as a test for potash, in all liquids not too diluted. As the perchlorate of soda is very soluble, the use of this acid enables us to distinguish, and to separate soda from potash.

The perchlorate of potash is easily formed by melting chlorate of potash, and heating it till the mass becomes thick and pasty, which takes place when $\frac{1}{3}$ of the oxygen is expelled. The residue is a mixture of chloride of potassium and perchlorate of potash, and the latter is easily purified by dissolving the whole in hot water, and allowing it to crystallize on cooling. The action of heat on chlorate of potash is thus expressed:



It must here be observed, that our knowledge of the compounds of chlorine and oxygen is far from being complete or satisfactory, and that Gay-Lussac and Millon, since the discovery by Balard of hypochlorous acid, have devoted attention to the subject. Millon, indeed, has published an elaborate memoir, in which he describes, under the name of chlorous acid, a compound ClO_2 , while he gives to the chlorous acid above described the name of hypochloric acid. The compound discovered by Davy, by acting on chlorate of potash with hydrochloric acid, and by him called euchlorine, by others protoxide of chlorine, and supposed by some to be a mixture of chlorine and chlorous acid (ClO_4), by others to be identical with chlorous acid, is, according to Millon, composed of $\text{Cl}_2\text{O}_8 = 2\text{ClO}_2 + \text{ClO}_7$. He calls it chlorochloric acid, and views it as composed of chlorous acid (ClO_2) and perchloric acid. In like manner, Millon has described another acid, obtained by the action of light on his chlorous acid in contact with cold water, and which he calls chloroperchloric acid. It is composed of $\text{Cl}_2\text{O}_{11} = \text{ClO}_2 + 2\text{ClO}_7$, and differs from the last in the proportion of chlorous and perchloric acids it contains.

Almost all of these compounds have properties so similar, that they are with difficulty distinguished from each other. Thus there are not less than five compounds, according to Millon, namely, ClO , ClO_2 , ClO_4 , Cl_2O_8 , and Cl_2O_{11} , which are volatile liquids, yielding deep yellow highly explosive vapors. He distinguishes ClO and ClO_2 from the others, as forming permanent salts with bases; the other three yield, with bases, a mixture of chlorate with chlorite (the acid in the latter being Millon's chlorous acid,

ClO_2), and the proportion of these salts is different in each case.

We have not space to enter more minutely into this very difficult but interesting subject. The researches of Millon are hardly completed, and require confirmation. In the meantime, the following table contains the compounds admitted by him, with his view of their true constitution:

Hypochlorous acid . . .	Cl O	
Chlorous acid	Cl O_2	
Hypochloric acid . . .	$\text{Cl O}_4 = \text{Cl}_4 \text{O}_{12} = 3 \text{Cl O}_2 + \text{Cl O}_7$	
Chloric acid	$\text{Cl O}_6 = \text{Cl}_2 \text{O}_9 = \text{Cl O}_2 + \text{Cl O}_7$	
Chlorochloric acid . . .	$\text{Cl}_2 \text{O}_8 = 2 \text{Cl O}_2 + \text{Cl O}_7$	
Chloroperchloric acid . .	$\text{Cl}_3 \text{O}_{11} = \text{Cl O}_2 + 2 \text{Cl O}_7$	
Perchloric acid	$\text{Cl O}_7 =$	

It will easily be seen that Millon admits, as independent compounds, only ClO , ClO_2 , and ClO_7 ; and that he considers all the others as compounds of ClO_2 with ClO_7 , in various proportions. This readily explains the formation of perchlorate of potash from chlorate: for, on this view, chlorate of potash is $\text{K O}, \text{ClO}_7 + \text{K O}, \text{ClO}_2$; and when heated, it is the latter (the chlorite) alone which is at first decomposed into chloride of potassium and oxygen. On this view, also, we see why all the three compounds, ClO_4 , $\text{Cl}_2 \text{O}_8$, and $\text{Cl}_3 \text{O}_{11}$, have properties so similar, and why they all yield, with potash, mixtures of chlorate and chlorite. For the details of the preparation and properties of these compounds, I must refer to the memoir of Millon, which is in the *Annales de Chimie et de Physique*, 1843, also in Liebig's *Annalen*, xlv., 281.

CHLORINE AND NITROGEN.

Perchloride of Nitrogen. $\text{N Cl}_4 = 156.07$.

SYN. Quadrichloride of Nitrogen.—This compound is obtained by allowing chlorine gas to come in contact with a solution of sal ammoniac at 90° or 100° . The gas is slowly absorbed, and an oily liquid appears in large drops on the surface of the liquid. By agitating the vessel, these fall down, being heavier than the solution, and should be received in a thick cup of lead, kept very clean.

The chloride of nitrogen is a yellowish oily liquid, distinguished for its tendency to explode by the mere contact of combustible matter, such as fat, oil, essential oils, phosphorus, &c. &c. The explosion is so violent, that even one drop of the liquid infallibly shatters any basin or bottle in which it explodes; and as it explodes often without any obvious cause, possibly from the contact of some minute portion of greasy matter, it is most dangerous to experiment on. A strong mask should be worn, and all the vessels employed should be scrupulously clean if it is necessary to make such experiments; it is better, however, not to attempt them. Both Dulong, the discoverer, and Davy, suffered very severely from

their researches on it. Each lost an eye, and the former lost several fingers also. For the sake of illustration, a drop or two may be exploded in the lead cup above mentioned, by simply touching them with a rod dipped in oil. The results of the explosion are chlorine and nitrogen gases. It is generally admitted that the formula of the compound is Cl_4N , and its formation may be thus explained — N H_3 , $\text{H Cl} + \text{Cl}_7 = 4 \text{H Cl} + \text{N Cl}_4$.

5. BROMINE. $\text{Br} = 78.39$.

This element is found in minute proportion in sea-water, in somewhat larger quantity in the water of the Dead Sea, in the bitter or mother liquor of sea-water, out of which the sea-salt has been crystallized, and in the mother liquid of many salt springs, from which, in like manner, the sea-salt has been separated. The mother liquor of the salt springs at Kreuznach is particularly rich in bromine. In all these cases, the bromine occurs as bromide of potassium, sodium, or magnesium.

To obtain it, the liquor, concentrated as much as possible, is exposed to a current of chlorine gas, which is continued as long as the liquor becomes darker in color from the bromine which is set free. The orange liquid thus obtained is to be agitated with ether, which rises to the surface, carrying with it all the bromine dissolved, which gives to the ether a hyacinth-red color. The solution of bromine in ether is then acted on by a slight excess of potash, which produces a mixture of bromate of potash and bromide of potassium: $6 \text{K O} + 6 \text{Br} = 5 \text{K Br} + (\text{K O}, \text{Br O}_3)$. The whole is dried up and ignited, when all the oxygen of the bromate is expelled, and only K Br is left. This bromide is mixed with rather more than half its weight of peroxide of manganese, and then distilled along with its own weight of oil of vitriol (previously mixed with half its weight of water); the red vapors of bromine are given off and condensed in a tube or receiver very well cooled. By rectification with a little chloride of calcium, the bromide is obtained dry and pure. The following is the action of the sulphuric acid on the bromide of potassium and peroxide of manganese: — $\text{K Br} + \text{Mn O}_2 + 2 \text{S O}_3 = \text{K O}, \text{S O}_3 + \text{Mn O}, \text{S O}_3 + \text{Br}$.

Bromine is, at ordinary temperatures, a deep brownish-red liquid, boiling at 113° ; its Sp. G. is 2.99. Its vapor resembles that of nitrous acid, but has a very peculiar disagreeable pungent smell. It is poisonous, and acts so strongly on the living membrane of the nose, that the mere smelling to a bottle of bromine is often followed by a painful sensation in the nostril, attended with a copious flow of tears, lasting for hours, or even for days.

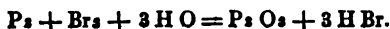
In all its relations, bromine is closely analogous to chlorine. It supports the combustion of phosphorus, and of many metals, like chlorine, and it bleaches organic colors. With hydrogen it forms hydrobromic acid, exactly analogous to hydrochloric acid; with

oxygen it forms as yet only one acid, Br O_3 , analogous to chloric acid. The analogy is equally striking when we compare the metallic bromides with the corresponding chlorides. Having so minutely described the relations of chlorine, this analogy will enable us to describe those of bromine very briefly. The affinities of bromine are less powerful than those of chlorine, so that the latter element disengages bromine from its compounds.

BROMINE AND HYDROGEN.

Hydrobromic Acid. $\text{H Br} = 79.89$.

To obtain this acid, phosphorus, bromine, and a little water are placed in contact, and the gas which is disengaged is collected over mercury. The change is the following :



Here, along with hydrobromic acid, phosphorous acid is produced.

Hydrobromic acid is a gas, transparent and colorless, fuming strongly when mixed with the air. Its Sp. G. is 2.73. It is, in smell, taste, absorbability by water, and indeed all its properties, hardly distinguishable from hydrochloric acid; but chlorine decomposes it, setting free bromine. The strongest solution of the acid is a fuming liquid of Sp. G. 1.29.

With metallic oxides it forms water and bromides, exactly as was explained under hydrochloric acid.



The bromides of lead, mercury, and silver, like the corresponding chlorides, are insoluble: the other bromides are soluble.

BROMINE AND OXYGEN.

Bromic Acid. $\text{Br O}_3 = 118.445$.

It has been already mentioned that bromic acid is formed in combination with potash, when bromine is acted on by that alkali. The bromate of potash is quite analogous to the chlorate; and bromic acid may be obtained in the same way as chloric acid, by the action of fluosilicic acid on the bromate of potash, or of sulphuric acid on bromate of baryta. Its properties are quite analogous to those of chloric acid.

There is some reason to think that bromine forms bleaching compounds, which, like those of chlorine, contain peculiar acids, bromous or hypobromous acids; and it is also probable that there exists a perbromic acid, analogous to perchloric acid. Our knowledge of these compounds, however, is very limited.

No compound of bromine and nitrogen is yet known. With chlorine, bromine forms a reddish-yellow, volatile, pungent liquid, which is said to be Br Cl_3 , a perchloride of bromine. When this

substance is acted on by potash, it yields chloride of potassium and bromate of potash.



6. IODINE. 1 = 126.57.

Iodine occurs in marine vegetables, and is found rather more abundantly in their ashes, as iodide of potassium, sodium, or magnesium. It is, of course, present in sea-water, but in so small a proportion as not to be easily detected. Iodide of silver has been found in Mexico, and some of the Silesian ores of zinc contain iodine.

It is best obtained from kelp, the ashes of various species of fucus, or other algæ. The kelp is lixiviated with water, and the solution evaporated as long as it deposits crystals. The mother liquor is precipitated by a mixture of 1 part of sulphate of copper and 2½ parts of sulphate of iron, and the precipitate, which is sub-iodide of copper, $\text{Cu}_2 \text{I}$, if heated with peroxide of manganese alone, or with the addition of sulphuric acid, yields the iodine as a purple vapor, which condenses in black crystalline scales on the cold part of the apparatus. It is purified by a second sublimation.

At ordinary temperatures iodine is solid, of a grayish-black color, and metallic lustre, like plumbago. It is often seen in acute rhomboidal plates; it is very brittle, and its Sp. G. is 4.948. It melts at 220° , and is converted, when dry, into purple vapor at 347° . Along with the vapor of water it volatilizes much more easily. It has a peculiar marine smell, and a rough acrid taste, and is poisonous.

Iodine is sparingly soluble in water, which takes up not more than $\frac{1}{1500}$ of its weight (1 lb. of water dissolves 1 grain of iodine). The solution has a pretty strong brownish-yellow color, and the smell of iodine. Alcohol and ether dissolve iodine abundantly, forming deep-brown solutions. Free iodine, whether in the form of vapor or of solution, gives to starch a deep-blue color, which affords a very delicate test for iodine, as well as for starch.

Iodine, like chlorine and bromine, enters into combination with phosphorus, metals, &c., when placed in contact with them, and frequently with the phenomena of combustion.

In liquids containing a minute trace of iodine in combination, it is best detected by adding fresh starch rubbed up with water, and then a very little chlorine, which may easily be done by simply inclining over the vessel the mouth of a phial containing some solution of chlorine, but not allowing the liquid to drop. There is always some chlorine gas in the upper part of the phial, which by its weight descends to the surface of the liquid to be tested, and the whole being agitated together, a blue tint, more or less deep, appears if iodine be present. Or oil of vitriol may be added to the liquid supposed to contain iodine, in a phial, and a slip of paper moistened with starch paste inserted between the

cork and the neck of the phial, so as to be suspended over the liquid. After a time, if iodine be present, the starch is tinged blue. In both tests the iodine is set free, for combined iodine has no action on starch. In the chlorine test, the superior affinity of chlorine seizes on the metal with which the iodine is united. Thus: $KI + Cl = KCl + I$.

In power of affinity iodine stands below bromine, as bromine does below chlorine. With metals it forms iodides extremely analogous to the chlorides and bromides. The iodides of lead, mercury, silver, and a few others are insoluble or sparingly soluble; most of the others are soluble. Some iodides possess beautiful colors, as those of lead and mercury. With hydrogen and oxygen iodine forms compounds, which, as far as they are known, correspond to those of chlorine and bromine with the same elements.

Iodine itself, and many metallic iodides, especially iodide of potassium, are much used in medicine as remedies in scrofula, and as discutients for glandular tumors in general. They are used both internally and externally in the shape of baths and ointments. Iodide of sulphur is also used medicinally. The long known efficacy of burnt sponge was shown by Coindet to depend on its containing, as the ashes of sea-plants or zoophytes generally do, a small proportion of iodine. The presence of iodine has also been detected in certain mineral springs, both in South America and in Europe, which had acquired celebrity as capable of curing goitre, a disease for which iodine seems to be a specific remedy, at least in all but the most advanced stages. On the whole, the discovery of iodine, which was made almost accidentally by Courtois, a soap-boiler, in Paris, in 1811, has proved a very valuable addition to the *Materia Medica*.

IODINE AND HYDROGEN.

Hydriodic Acid. $HI = 127.57$.

This acid, which is exactly similar in properties to hydrochloric and hydrobromic acids, is best obtained, in the form of gas, by



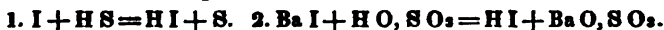
Fig. 43.

gently heating a mixture of one part of phosphorus and 16 of iodine, stratified with moistened sand or powdered glass, in a small tube. The gas may be collected over mercury, or absorbed by water, if the liquid acid is required. As iodine and phosphorus act very violently on each other, and indeed take fire in the open air, they ought to be brought in contact in the retort, and it is even preferable to fill it first with carbonic acid. Millon has lately proposed another method, namely, to

dissolve in a very small quantity of water, in a retort or flask, some iodide of potassium, to add to this as much iodine as it will dissolve, and a moderate quantity of phosphorus in small pieces, and then to apply a gentle heat. In this way the action is more easily regulated.

Hydriodic acid gas is transparent, colorless, acid to the taste, and suffocating to the smell. It has a Sp. G. of 4.385, fumes strongly in the air, and is absorbed by water to as great an extent as hydrochloric acid gas, from which it is not to be easily distinguished, except by the action of chlorine or bromine, which, seizing the hydrogen, disengage the purple vapors of iodine.

The aqueous solution is prepared by passing a current of the gas through water, by passing a current of sulphuretted hydrogen through water in which iodine is suspended, or by adding diluted sulphuric acid to a solution of iodide of barium. The two latter methods are thus expressed :



When very concentrated, this solution acquires a Sp. G. of 1.700. It does not keep well, however, being decomposed by the oxygen of the air, with separation of iodine, $\text{HI} + \text{O} = \text{H O} + \text{I}$. With solution of bichloride of platinum, hydriodic acid strikes a deep brownish-red color ; with nitrate of bismuth a dark brown, nearly black. Hydriodic acid can dissolve a large quantity of free iodine, which gives it a deep brown color ; hence the gradual decomposition of the acid by the air is shown by its becoming continually darker, from dissolving the iodine separated.

With metallic oxides, this acid forms water and iodides. Thus, with solution of silver, it forms a yellowish-white precipitate of iodide of silver ; with solution of lead, a fine yellow precipitate of iodide of lead ; and with solution of peroxide or bichloride of mercury, a beautiful scarlet precipitate of biniodide of mercury. With chlorine and starch, it of course gives the blue iodide of starch.

IODINE AND OXYGEN.

a. Iodic Acid. $\text{I O}_2 = 166.675$.

Analogous to chloric and bromic acids. To obtain it, iodine is boiled in a long-necked flask with the strongest nitric acid, when it is gradually oxidized, and the excess of nitric acid is expelled by a moderate heat. Or 9 parts of iodate of baryta are boiled with a mixture of 2 parts of oil of vitriol and 10 or 12 of water. The filtered liquid by evaporation yields iodic acid as a white crystalline solid.

It is very soluble in water and very acid to the taste. It is easily resolved into iodine and oxygen by a red-heat ; and it also yields oxygen to many organic substances, and is used as a test for morphia or its salts, which it colors dark brown.

The salts of iodic acid, like the chlorates and bromates, deflagrate with combustible bodies at a red-heat, but not so powerfully as chlorate of potash. Iodic acid forms two series of salts, with 1 and 2 eq. of base respectively.

Iodic acid is decomposed, iodine being separated, by hydrochloric and hydrobromic acids, also by sulphuretted hydrogen and sulphurous acid. It may, therefore, be recognized by using any of these re-agents, followed by starch, to detect the free iodine.

b. Periodic Acid. $\text{IO}_7 = 182.661$.

Analogous to perchloric acid. Formed when iodate of soda is heated with bleaching liquor (chloride of soda), or when chlorine is passed through a hot solution of 7 parts of dry carbonate of soda in 100 of water, in which 1 part of iodine is suspended, as long as a white crystalline salt is deposited. This is periodate of soda. It is dissolved in dilute nitric acid, and nitrate of lead added, which forms a precipitate of periodate of lead. This last salt is boiled with diluted sulphuric acid, avoiding excess, and the filtered solution or evaporation, yields crystals of periodic acid in transparent plates.

When heated, this acid is dissolved into oxygen and iodic acid. It forms with bases two series of salts, with 1 and 2 eq. of base.

It is at present doubtful if there exist compounds of iodine with less oxygen than iodic acid. Salts have been obtained, having a composition represented by MO, IO : but the supposed hypo-iodous acid, IO , has not been isolated, and these salts are very easily resolved into a mixture of iodates and iodides, of which they may possibly be, in reality, composed; for $6(\text{MO}, \text{IO}) = 5\text{MI} + \text{MO}, \text{IO}_5$.

IODINE AND NITROGEN.

When iodine is placed in contact with aqua ammoniæ, there is formed a black powder, the composition of which is either NI , or NI_3 . It explodes with very great violence, often spontaneously, on becoming dry by exposure to the air; and at all times by very slight causes, a slight blow, or friction. It is, therefore, a very dangerous substance.

IODINE AND CHLORINE.

Iodine readily combines with chlorine, forming apparently two compounds, ICl and ICl_3 , which, however, are not well known. Both of them are volatile liquids, of a brown color and exceedingly pungent odor, strongly affecting the eyes. When acted on by alkalies, they yield iodate of the base and chloride of the metal, while iodine is set free. Water, also, decomposes them.

IODINE AND BROMINE.

Iodine appears, also, to form two compounds with bromine, of which one is solid, the other liquid. With alkalies they yield a mixture of iodate of the oxide and bromide of the metal, with free iodine.

7. FLUORINE. $F = 18.74$.

This element occurs in the mineral kingdom combined with calcium, as fluor spar; also in small proportions as an element of mica and of topaz. Fluoride of calcium is also in minute quantity an ingredient of animal bones, especially of the enamel of the teeth, and of the urine of some animals. It is very remarkable, that fossil bones contain much more fluoride of calcium than recent bones; in some cases even 10 per cent. Even human bones of the historical period, as bones from the tombs of Egypt, or from Pompeii, appear to contain more fluoride of calcium than those of the present day.

Fluorine has not yet been isolated, owing no doubt to its very powerful affinities, which cause it, even if separated from one substance, instantly to unite with another, derived from the substance of the vessel used for the experiment. Its properties in the separate state, are therefore unknown. Knox and Baudrimont have of late made repeated efforts to isolate fluorine, using vessels of fluor spar, &c., but as yet without satisfactory results; although it is conjectured, from some of these experiments, to be a yellow gas, not unlike chlorine. It is probable, however, that the presence of chlorine has been the cause of this apparent resemblance.

The affinities of fluorine for metals and for electro-positive elements in general, are very powerful indeed; probably surpassing those of oxygen. On the other hand, it has not been obtained in combination with any of the more negative elements, such as oxygen, chlorine, bromine, and iodine. These considerations render it probable that it is a highly negative body; and the character of its compounds with hydrogen and metals indicates a strong analogy between fluorine and chlorine, bromine and iodine.

FLUORINE AND HYDROGEN.

Hydrofluoric Acid. $HF = 19.74$.

Syn. Fluoric Acid. — This acid is obtained by the action of oil of vitriol on fluoride of calcium (fluor spar). The powdered mineral is gently heated with the acid in a retort of lead, silver, or platinum, as glass and porcelain are destroyed by the process, and the acid condensed in a receiver of the same metal, surrounded by a freezing mixture. The action is thus expressed:



The acid appears as a very volatile liquid, strongly acid and corrosive, fuming in the air. A drop on the skin burns it like red-hot iron, and causes a painful sore, not easily healed. Even the vapors, if they are allowed to come much in contact with the hand, are apt to cause painful sores under the nails. The acid, even when much diluted, or in the form of vapor, rapidly corrodes glass, and may be used for etching on glass plates.

With metallic oxides hydrofluoric acid gives rise to water and metallic fluorides: $\text{H F} + \text{M O} = \text{H O} + \text{M F}$. The affinity of fluorine for silicon is such, that hydrofluoric acid decomposes all silicious compounds; and this explains its corrosive action on glass and porcelain. Berzelius has employed this acid as a means of analyzing silicious minerals. As the fluoride of silicon is gaseous, any such mineral, if digested with hydrofluoric acid, soon loses all its silica, and is dissolved, so that the other ingredients may be determined.

No compound of fluorine with any of the preceding elements, except hydrogen, is yet known. Its compounds with silicon, boron, and the metals, will come to be described in their natural places.

8. SULPHUR. $\text{S} = 16.12$.

Sulphur occurs, especially in volcanic districts, in a state of purity, often crystallized. It is also found in combination with oxygen, as sulphuric acid, in gypsum, heavy spar, and many other minerals, with hydrogen as sulphuretted hydrogen, in mineral waters, and above all with metals, — most abundantly with lead, iron, copper, &c. Finally, it is an essential ingredient of vegetable and animal fibrine, albumen, and caseine, and as such is indispensable to vegetation and to animal life. Some essential oils, such as those of mustard, of horse-radish, of assafetida, &c., contain a large proportion of sulphur.

Native sulphur is purified by sublimation, when the sulphur assumes the form of a fine light powder, flowers of sulphur. It also occurs in cylindrical sticks, roll sulphur, which has been melted and run into moulds.

Sulphur is a solid, of a pale yellow color, of Sp. G. 1.99, and when pure has neither taste nor smell. It melts at 226° , and boils at 600° , yielding a deep brownish-yellow vapor, or gas. At temperatures below 390° , the melted sulphur is very fluid, but if heated to and beyond that point, it becomes so thick and viscid that it cannot be poured out of the vessel. If the heat be still increased, so as to approach the boiling point of sulphur, it again becomes fluid, although not so much so as at 230° or 240° . If now allowed gradually to cool, it first becomes thick, and on cooling still further, quite fluid again. When thrown into water in its most fluid state, (at 240°), it instantly becomes a hard brittle

yellow mass; but if heated to between 500° and 600° for some time, and then thrown into water, it remains brown and transparent, and is so flexible that it may be kneaded in the fingers, and drawn into threads. In this state it may be used for taking copies of reliefs or intaglios; for in a few days it becomes solid, crystalline, hard, and yellow, retaining very sharp impressions.

Sulphur is a very bad conductor of heat and of electricity; hence it becomes strongly electric by friction. It crystallizes in two distinct and irreconcilable forms, probably from a difference of temperature; from a solution in sulphide of carbon, or chloride of sulphur, in acute rhombic octohedrons; and when melted and allowed to cool, in oblique rhombic prisms. It is thus dimorphous, and besides occurs in an altogether amorphous state when heated to 500° and thrown into cold water (*see above*).

Sulphur is insoluble in water; soluble in alcohol, ether, and oils, also in bisulphide of carbon, and in chloride of sulphur.

The affinities of sulphur are powerful: it forms numerous and important compounds, especially those with oxygen, hydrogen, and the metals. With many metals it combines when heated along with them, the combination being accompanied with the development of heat and light. In other words, metals undergo combustion with sulphur, just as with oxygen or chlorine. The compounds of sulphur with metals are called sulphides.

Besides roll sulphur, and sublimed sulphur, there is another form, namely, precipitated sulphur or lac sulphuris. This is a light powder, nearly white, obtained by boiling sulphur with water and an alkali, and adding an acid to the solution, when sulphur separates as a precipitate. It is very finely divided, and appears to contain some water, although not perhaps chemically combined.

Sulphur is much used both externally and internally in medicine. It is a mild laxative, and acts as a specific when employed as ointment in prurigo and some other cutaneous affections.

When heated to above 560° in the open air, sulphur takes fire and burns with a blue flame, producing a very suffocating gas, which is sulphurous acid, the only compound of sulphur with oxygen capable of being formed by direct combination of its elements. There are, however, several other compounds of sulphur and oxygen; and one of them, the sulphuric acid, is perhaps the most important agent possessed by the chemist.

SULPHUR AND OXYGEN.

a. Sulphurous Acid. $\text{SO}_2 = 82.146$.

This is the gas produced when sulphur burns in the air or in oxygen gas. It is best obtained pure by heating oil of vitriol with mercury or copper. Either of these metals deprives a part of the sulphuric acid of oxygen, and the oxide thus formed combines with the rest of the acid. Thus:



The gas may be collected over mercury, being absorbed by water.

Sulphurous acid is a transparent and colorless gas: it has a peculiar disagreeable taste, and a most suffocating smell, and is very injurious when respired; its effects, such as hard cough, constriction in the trachea, &c., continuing for a long time. It is also very injurious to vegetation. Its Sp. G. is 2.222. It bleaches organic matters, such as flowers, without destroying the coloring matter as chlorine does; for the addition of a stronger acid produces the same red as if the color had not been bleached. Sulphurous acid gas is liquefied by intense cold, and yields a very volatile liquid.

Water absorbs about 50 times its volume of this gas, forming liquid sulphurous acid, as it is called, properly an aqueous solution of the acid. This solution has the suffocating smell, peculiar taste, and bleaching properties of the gas. If exposed to the air, it gradually absorbs oxygen, and passes into sulphuric acid. Nitric acid also converts sulphurous acid into sulphuric acid.

With bases, sulphurous acid forms salts which are called sulphites. They have all the unpleasant taste of the acid, and when acted on by stronger acids, give off the suffocating smell of burning sulphur. These salts, as well as the acids, are occasionally used by the chemist as deoxidizing agents, the sulphurous acid having a very powerful attraction for a third eq. of oxygen to form sulphuric acid. The oxides of mercury, silver, gold, and platinum, in solutions of their salts, are reduced to the metallic state by sulphurous acid.

b. Sulphuric Acid. $\text{S O}_2 = 40.159$.

Oil of vitriol, or hydrated sulphuric acid $= \text{H O, S O}_2$ or $\text{H, SO}_4 = 49.272$.

The first of these formulæ represents dry or anhydrous sulphuric acid, or at least a substance having the composition of oil of vitriol, *minus* 1 eq. of water. But it is very doubtful if this compound really possesses acid properties; and we consider as true sulphuric acid the well-known compound of oil of vitriol, which may be viewed either as a compound of water (a hydrate), or a compound of hydrogen (a hydrogen acid, analogous to hydrochloric acid).

Anhydrous sulphuric acid is obtained by distilling dried basic persulphate of iron, $\text{Fe}_2 \text{O}_3 \text{ S O}_2$, when the peroxide of iron is left, and the sulphuric acid distils over, condensing in the receiver (if kept dry) as a white crystalline solid, which gives off thick fumes in moist air, is converted into vapor at about 160° , and has so strong an affinity for the elements of water, that when thrown

into water it hisses as a red-hot iron would do, combining with the water and forming oil of vitriol.

This compound, SO_3 , enters into few combinations, and does not form the ordinary sulphates, unless the elements of water be present. Its claim to the character of an acid is therefore doubtful, and depends on the view which makes oil of vitriol a hydrate, H O, SO_3 .

OIL OF VITRIOL, OR TRUE SULPHURIC ACID.

This acid cannot be formed by the direct union of its elements, but is produced by causing sulphurous acid to unite with an additional eq. of oxygen, in contact with the elements of water. Sulphur is burned with the aid of nitrate of potash or soda, thus yielding a mixture of sulphurous acid and nitrous acid gases. These gases are conducted into leaden chambers along with atmospheric air and steam, the bottom of the chambers being also covered with water. All the changes which take place are not thoroughly understood; but this much is certain, that the sulphurous acid is oxidized at the expense of the nitrous acid, reducing it to the state of deutoxide of nitrogen:



The water becomes gradually charged with oil of vitriol, and the deutoxide of nitrogen, being reconverted into nitrous acid by contact with the oxygen of the air, again yields half its oxygen to a fresh portion of sulphurous acid; and thus, for an indefinite period, acts as a carrier of oxygen from the air to the sulphurous acid. In this way, a comparatively small quantity of nitrate is required for a large quantity of sulphur.

When the liquid has become very acid, it is boiled down in platinum or glass vessels until it acquires the Sp. G. 1.845, when it begins to be converted into vapor itself, all the superfluous water being now driven off. The remaining liquid is now oil of vitriol.

Oil of vitriol, or hydrated sulphuric acid, is an oily liquid, nearly twice as heavy as water, very acid and corrosive, charring all organic matters, apparently by its very strong attraction for water, or its elements. It freezes at -31° , and boils at 617° .

The oil of vitriol prepared at Nordhausen and other places, by the old process of distilling partially dried green vitriol, (whence its name), often fumes on exposure to the air, and is called Nordhausen oil of vitriol, or fuming sulphuric acid. It is, in fact, a compound of 1 eq. anhydrous acid, and 1 eq. of common or hydrated sulphuric acid $= \text{H O, 2 SO}_3$, or $\text{H O, SO}_3 + \text{SO}_3$. When the fuming acid of Nordhausen is distilled at about 290° , anhydrous acid distils over, and hydrated acid remains behind. Most specimens of the fuming acid contain 5 to 8 per cent. of hydrated acid, in excess beyond the formula $\text{H O, SO}_3, + \text{SO}_3$.

If we view common sulphuric acid as a hydrate of the anhydrous acid, then we have several hydrates of which the fuming acid is one. There are, 1st, fuming acid, $\text{H O}, 2 \text{ S O}_2$; 2nd, common acid, $\text{H O}, \text{S O}_2$; 3rd, $\text{H O}, \text{S O}_2 + \text{H O} = \text{S O}_2 + 2 \text{ H O}$, 4th, $\text{H O}, \text{S O}_2 + 2 \text{ H O} = \text{S O}_2 + 3 \text{ H O}$.

The third hydrate has a Sp. G. of 1.78, and at 39° crystallizes in large regular transparent crystals. Of the two eqs. of water it contains, one is easily replaced by an eq. of a neutral salt; thus, $\text{H O}, \text{S O}_2 + \text{H O}$ gives rise to bisulphate of potash ($\text{H O}, \text{S O}_2 + \text{K O}, \text{S O}_2$), when the second eq. of water is replaced by neutral sulphate of potash. The first eq. of water can only be displaced by an eq. of a base; as when $\text{H O}, \text{S O}_2$ gives rise to neutral sulphate of potash, $\text{K O}, \text{S O}_2$.

The fourth hydrate may be regarded as the third + 1 eq. water of crystallization. Its Sp. G. is 1.632. If heated to 212° , it loses water, until nothing remains but the third hydrate.

If we view oil of vitriol, $\text{H O}, \text{S O}_2$, as the original compound from which all the others are derived, then the fuming acid will be a compound of 1 eq. of it with 1 eq. of anhydrous acid, and the other two hydrates will contain 1 eq. oil of vitriol, with 1 and 2 eq. of water respectively.

The attraction of oil of vitriol for water is very strong. When these liquids are mixed, a great amount of heat is developed, depending partly on the energetic chemical action, partly on the condensation which takes place; for the volume of the diluted acid, after cooling, is found to be considerably less than that of the acid and water before mixture. Oil of vitriol attracts moisture strongly from the atmosphere, becoming rapidly weaker if exposed.

This property is made use of in Leslie's ingenious method of freezing water in vacuo by its own evaporation; the evaporation being greatly hastened by the presence of a vessel containing oil of vitriol, to absorb the vapor as fast as it is formed. In chemical researches, where heat is to be avoided, liquids are frequently concentrated by being placed either in vacuo, or simply under a bell-jar, along with a basin of this acid. Many gases, such as chlorine, carbonic acid, &c., &c., are most conveniently deprived of moisture by causing them to pass through oil of vitriol, which arrests all the water they contain. It is this powerful attraction for water that is the principal cause of the charring or corrosion of organic matters by this acid. When wood, for example, is charred by sulphuric acid, the acid is found to have undergone no further change, except that it is more diluted, having combined with water, the elements of which are derived from the wood. Now, as wood may be represented as carbon + water, the removal of water is, of course, accompanied by a separation of carbon.

No chemical agent is applied to a greater number of purposes in the useful arts than sulphuric acid; and hence its manufacture is of very high importance. Since the introduction and improvement of the process now followed, the price of this invaluable product has been diminished to a trifling fraction of what it was; and its applications have in consequence become vastly more numerous and important. These will be described in their proper places; but it may here be mentioned, that two of the most extensive and valuable chemical manufactures, those of soda from sea-salt, and of bleaching-powder, are entirely dependent on the supply of sulphuric acid at a low price; and that not only these manufactures have benefited by every reduction in the cost of making the acid, but also all the important arts to which soda and bleaching-powder are essential; such as soap-making, glass-making, and the cotton and calico-printing trades.

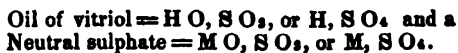
The uses of this acid to the scientific chemist are innumerable; almost every page of chemical works bears evidence of this. In medicine, diluted sulphuric acid is used as a refrigerant, and care should be taken to avoid administering it along with incompatible substances, such as all bases, and many salts.

The commercial acid is never pure. The chief impurities are sulphate of lead, derived from the lead chambers; arsenic, and occasionally selenium, derived from the sulphur; and nitrous, or hyponitrous acid. It is purified by distillation, the first portions being rejected, as containing the nitrous acid. The operation in glass vessels requires caution, as from the high temperature, and the tendency of the acid to boil with succussions, the retorts are liable to be broken. The danger is best avoided by introducing into the retort some coils of platinum wire, and heating chiefly from above, so that the ebullition may go on at the surface principally.

The pure distilled acid is perfectly colorless, and when cold, devoid of smell; it ought also to be entirely dissipated when heated on platinum, leaving no residue.

The presence of sulphuric acid, whether free or combined, is detected in solutions by the characteristic property of forming, with any soluble compound of barium, a precipitate of sulphate of baryta, which is not only insoluble in water, but also in the strongest acids.

With bases sulphuric acid forms salts, which are called sulphates. In the neutral sulphates, the water of the oil of vitriol is replaced by its equivalent of a metallic oxide; or, if we regard oil of vitriol as a hydrogen acid, then in the neutral sulphates the hydrogen is replaced by its equivalent of a metal. Thus we have,



The acid in the neutral sulphates, as may be seen by their formula, contains three times as much oxygen as the base by which it is neutralized. This holds true also in the sulphates of sesquioxides, the formula of which is $M_2 O_3, 3 S O_3$, or $M_2, 3 S O_4$. The acid sulphates, which are numerous, contain twice as much acid as the neutral; thus acid sulphate, or bisulphate of potash, is $K O, H O, 2 S O_3$; when the acid contains six times as much oxygen as the base.

The affinity of sulphuric acid for most bases is stronger than that of all other acids. In a red-heat, phosphoric and boracic acids, being fixed in the fire, expel sulphuric acid from its salts. In solution, sulphate of lime is decomposed by oxalic and racemic acids, which seize the lime; and sulphate of potash, by tartaric, racemic, and perchloric acids, which combine with the potash. In other circumstances, however, the sulphuric acid appears stronger than the acids just mentioned; thus, it decomposes phosphates in the cold, and tartrates, or perchlorates, with the aid of a gentle heat.

Many sulphates of metallic oxides, when exposed to a red-heat along with charcoal, or in a current of hydrogen gas, lose all the oxygen they contain, and are changed into sulphides of the metal. When charcoal is used, the oxygen escapes as carbonic oxide, or carbonic acid gas; when hydrogen is employed, the oxygen is given off as water. Thus, $M O, S O_3 + C = 4 C O + M S$; or $M O, S O_3 + H_2 = 4 H O + M S$.

c. Hyposulphurous Acid. $S_2 O_2 = 48.266$.

This acid is unknown in the separate state. Its salts are formed when sulphur is boiled with a solution of sulphite. Thus, if sulphite of soda is boiled with sulphur, we have $Na O, S O_2 + S = Na O, S_2 O_2$. The salts of this acid are called hyposulphites, and they are all, except the hyposulphite of baryta, easily soluble in water. Hyposulphites are also formed when alcalies are fused at a low heat with sulphur, and when solutions of alkaline sulphides are exposed to the air so as to be slowly oxidized.

When we attempt to separate hydrosulphurous acid from any of its salts, it is instantly resolved into sulphurous acid and sulphur, $S_2 O_2 = S O_2 + S$. When oxidized by nitric acid, the hyposulphites are converted into bisulphates: $K O, S_2 O_2 + O = K O, 2 S O_3$.

This acid, and all its soluble salts, possess the remarkable property of dissolving all the compounds of silver, even the chloride, which is insoluble in the strongest acids; and the solution thus formed has a very intense sweet taste, with a metallic after-taste. This property has been made available in the daguerreotype, for the purpose of dissolving the sensitive coating of iodide from the plate of silver, after exposure to light, and thus fixing the image

already formed. For this purpose, hyposulphate of soda is now prepared in considerable quantity.

d. Hyposulphuric Acid. $S_2 O_4 = 72.355$.

This acid is formed, along with sulphuric acid, when sulphurous acid is oxidized by means of peroxide of manganese: $3 S O_2 + 2 M n O_2 = M n O, S_2 O_4 + M n O, S O_3$. The solution thus obtained is decomposed by baryta, or by sulphide of barium, by which the manganese is separated as oxide or as sulphide, and the sulphuric acid as sulphate of baryta, and hyposulphate of baryta, a soluble salt, is obtained: $M n O, S_2 O_4 + B a S = B a O, S_2 O_4 + M n S$; and $M n O, S O_3 + B a S = B a O, S O_3 + M n S$. The filtered solution is then mixed with just as much diluted sulphuric acid as is sufficient to separate the baryta as the insoluble sulphate, and the liquid now contains hyposulphuric acid: $B a O, S_2 O_4 + H O, S O_3 = B a O, S O_3 + H O, S_2 O_4$.

When concentrated by evaporation in vacuo, hyposulphuric acid forms a syrup liquid of a very acid taste, and devoid of smell. When heated, it yields sulphurous acid gas, while sulphuric acid remains, $S_2 O_4 = S O_2 + S O$. Its salts, when ignited, give off sulphurous acid, while sulphates remain; $M O, S_2 O_4 = S O_2 + M O, S O_3$.

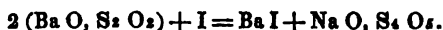
With bases, this acid forms salts, most of which crystallize with great facility. It is not applied to any useful purpose.

e. Sulphuretted Hyposulphuric Acid. $S_3 O_4 = 88.475$.

Discovered by Langlois. When bisulphite of potash is digested along with sulphur and water, without boiling, a salt is gradually produced, which contains this new acid. The acid may be isolated by means of perchloric acid, which removes the potash. It forms an acid liquid, which is slowly decomposed, and when heated is resolved into sulphurous acid, sulphur, and sulphuric acid; for $S_3 O_4 = S O_2 + S + S O_3$. The theory of its formation is not yet fully understood, and the acid itself is as yet but little known. The salt which it forms with potash crystallizes easily, and when heated yields sulphurous acid, sulphur, and sulphate of potash: $K O, S_3 O_4 = S O_2 + S + K O, S O_3$.

f. Bisulphuretted Hyposulphuric Acid. $S_4 O_4 = 104.595$.

Discovered by Fordos and Gelis. When iodine is dissolved in the solution of a hyposulphite, as hyposulphite of soda or baryta, the following change takes place:



Here 2 eq. of hyposulphite of baryta and 1 eq. of iodine yield 1 eq. of iodide of barium and 1 eq. of the baryta salt of the new

acid. Alcohol dissolves the former, and leaves the latter pure. By the cautious addition of diluted sulphuric acid, the baryta is precipitated, and the new acid is obtained dissolved in water. It resembles the two preceding acids, and, like the last, it is resolved, when heated, into sulphurous acid, sulphur, and sulphuric acid, $S_4O_8 = SO_2 + S_2 + SO_3$. Here the quantity of sulphur separated is exactly double of that yielded by the acid last described.

The salts of this acid crystallize, and when heated yield 1 eq. of sulphurous acid, 2 eqs. of sulphur, and 1 eq. of sulphuric acid; $MO, S_4O_8 = SO_2 + S_2 + MO, SO_3$.

The following table exhibits the composition of the compounds of sulphur and oxygen above described, with their formula, and those of their neutral salts, according to the older and newer views of the constitution of acids:

	Older View.		New View.	
	Acids.	Salts.	Acids.	Salts.
Sulphurous Acid . . .	$H O, S O_2$	$M O, S O_2$	$H, S O_2$	$M, S O_2$
Sulphuric Acid . . .	$H O, S O_3$	$M O, S O_3$	$H, S O_3$	$M, S O_3$
Hyposulphurous Acid .	$H O, S_2O_2$	$M O, S_2O_2$	H, S_2O_2	M, S_2O_2
Hyposulphuric Acid . .	$H O, S_2O_3$	$M O, S_2O_3$	H, S_2O_3	M, S_2O_3
Acid of Langlois . . .	$H O, S_3O_3$	$M O, S_3O_3$	H, S_3O_3	M, S_3O_3
Acid of Fordos and Gelis	$H O, S_4O_3$	$M O, S_4O_3$	H, S_4O_3	M, S_4O_3

Now, when we reflect that all the salts in the above table, although containing only 1 eq. of metal or of base, are neutral, while the acids, according to the older view, and considered as oxygen compounds, contain different proportions of oxygen, we can hardly hesitate to prefer the newer view, according to which all true acids are hydrogen compounds, and their capacity of saturation, or power of neutralizing bases, depends, not on the oxygen they contain, but on the amount of hydrogen replaceable by metals, which, in all these acids, is 1 equivalent. This at once accounts for the fact that acids so different in composition should all form neutral salts with the same quantity of base. The difference lies in the compound radicals, which, according to this theory, are united with hydrogen in the acids, and the composition of which may vary *ad infinitum* without affecting the neutralizing power, provided the replaceable hydrogen continue unaltered. In fact, an acid has been described by Régnault in which 1 eq. of chlorine is added to the radical of sulphurous acid; and another by Pelouze, in which 1 eq. of hyponitrous acid is added to the same radical, without affecting the power of neutralization.

If we take the radical of sulphurous acid as the first member of the series, all the above acids may be thus represented

Sulphurous Acid	$H + SO_2$
Sulphuric Acid	$H + (SO_2 + O)$
Hyposulphurous Acid . .	$H + (SO_2 + S)$
Hyposulphuric Acid . .	$H + (SO_2 + SO_2)$
Acid of Langlois	$H + (SO_2 + SO_2 + S)$
Acid of Fordos and Gelis	$H + (SO_2 + SO_2 + S_2)$
Chlorosulphuric Acid . .	$H + (SO_2 + Cl)$
Nitrosulphuric Acid . .	$H + (SO_2 + NO)$

Here we see that the addition to the radical SO_2 , of oxygen, of sulphur, of its own elements SO_2 , of the same with sulphur, of chlorine, or of hyponitrous acid, does not affect the neutralizing power, that being dependent on the amount of replaceable hydrogen, which is the same in all.

I have here entered into some detail on the subject of the true constitution of acids, because the acids of sulphur form an admirable illustration of the superior simplicity of the new view of acids and salts, according to which, an acid may be defined as, — A compound of hydrogen with a radical, simple or compound, in which the hydrogen may be replaced by its equivalent of metal: while a salt is, — A combination of a simple or compound radical with a metal: the different salts of one metal corresponding with the oxides of, the same metal.

It is obvious that even when a chemical combination or change is represented in a formula according to the old view, as is the case in almost all existing works, we can easily transpose the formula so as to express the new view. Thus, sulphate of potash, on the old view, is KO, SO_3 ; on the new it is K, SO_4 ; or if we express the action of iron on sulphuric acid, on the former view, by $Fe + HO, SO_3 = H + FeO, SO_3$, it is more simple on the latter, $Fe + H, SO_4 = H + Fe, SO_4$.

While, therefore, in order to avoid confusion, I shall generally use, in equations, the older formula for acids and salts, I shall give the new formula for the principal acids, as I have done for sulphuric and nitric acids, so that the student may, if he please, convert the equations into the new form.

SULPHUR AND HYDROGEN.

a. Sulphuretted Hydrogen. $HS = 17.12$.

Syn. Hydrosulphuric Acid.—This compound is formed when hydrogen and sulphur come in contact in the nascent state. It is best prepared by causing diluted hydrochloric or sulphuric acid to act on sulphide of iron in the apparatus, p. 68, when sulphuretted hydrogen is disengaged as a gas, which may be collected over warm water, or solution of salt. The action is as follows: $FeS + HCl = FeCl + HS$.

Sulphuretted hydrogen is a gas, transparent and colorless, having a very offensive and peculiar smell, which is well known as

that of putrid eggs. It is liquefied by a pressure of 17 atmospheres. When respired, even although much diluted with air, it is highly deleterious, and as it is often formed where animal matters or excrements putrefy, as in burying-vaults and cloacæ, it not unfrequently causes the death of workmen who suddenly come in contact with it. The smell of the gas ought, in all cases, to be viewed as a warning of danger. The presence of the gas may also be recognized by its power of blackening the salts of lead, owing to the formation of the black sulphide of lead.

This gas is combustible, burning with a bluish flame, and producing sulphurous acid gas and water. Its Sp. G. is 1.177. Water absorbs 2 or 3 times its volume of the gas, and acquires its smell and a nauseous sweetish taste. By contact with the air, the solution is gradually decomposed; water is formed and sulphur deposited. Sulphuretted hydrogen water must, therefore, be kept in small phials, quite full and closely stopped.

Sulphuretted hydrogen has the properties of a weak acid; it reddens litmus feebly, and acts on bases, forming with them water and metallic sulphides: $\text{H S} + \text{M O} = \text{H O} + \text{M S}$. As the sulphides of some metals are soluble while those of others are insoluble; as moreover the oxides of some of the latter are not decomposed by sulphuretted hydrogen when dissolved in an acid, the action of this gas on solutions of metals in acids affords us a great deal of information, according as a precipitate of sulphide is formed or not, the color of the precipitate being also frequently characteristic, as will be described under the individual metals: this renders sulphuretted hydrogen a most useful re-agent in detecting and separating from each other metallic compounds.

Mineral water exists, as at Harrowgate, which contains sulphuretted hydrogen, easily recognized by its smell and by the property of blackening the salts of lead, silver, and several other metals. The gas in these waters arises from the slow and continued putrefaction of vegetable matters containing sulphur, such as albumen, fibrine, &c. These sulphurous waters are used in medicine, both internally and externally (as baths), with great advantage. In many cases the artificial sulphuretted hydrogen water, formed by passing the gas through water, previously boiled and allowed to cool, may be substituted for them.

b. Persulphuretted Hydrogen. H S_2 ? or H S_2 !

This compound is formed when alkalies, such as potash or lime, are boiled with excess of sulphur, and the solution, which is of a deep yellow or orange color, is poured into a large excess of moderately strong hydrochloric acid, made by mixing equal parts of concentrated acid and water. A heavy, somewhat viscid, transparent, yellowish liquid falls to the bottom, which is the compound

in question. The precise nature of all the changes which take place in this process is not known; but it is probable that a persulphide of the metal is formed in the first stage, such as persulphide of potassium KS_2 ; and that a hyposulphite is generated at the same time, possibly according to the formula $3\text{KO} + \text{S}_2 = \text{KO}, \text{S}_2\text{O}_2 + 2\text{KS}_2$. In the second stage, we have probably $\text{KS}_2 + \text{HCl} = \text{KCl} + \text{HS}_2$. But as the composition of persulphuretted hydrogen is not precisely determined, and as the persulphide appears to dissolve an excess of sulphur, we cannot be certain that this is the true explanation. Thénard considers persulphuretted hydrogen HS_2 , and to be analogous to the peroxide of hydrogen H_2O_2 . But his own analysis always gave far more sulphur than corresponds to his formula, and the analogy he pointed out is very obscure and doubtful.

Persulphuretted hydrogen soon undergoes spontaneous decomposition, even if kept in sealed tubes, resolving itself into sulphur and sulphuretted hydrogen. In a strong sealed tube, the sulphuretted hydrogen, by its own pressure, is liquefied, and floats above the sulphur, which is deposited in transparent crystals. Persulphuretted hydrogen seems to have feeble acid properties. In contact with alkalies, it reproduces water and the metallic persulphuret. $\text{HS}_2 + \text{KO} = \text{HO} + \text{KS}_2$.

SULPHUR AND NITROGEN.

Sulphide of Nitrogen.* $\text{NS}_2 = 62.51$.

When chloride of sulphur, SCl_2 , acts on dry ammonia, NH_3 , a compound is formed, $\text{SCl}_2, 2\text{NH}_3$. By the action of water on this there is formed, among other products, a greenish yellow solid body, which is sulphide of nitrogen NS_2 . By contact with water, it is gradually converted into hyposulphurous acid and ammonia: for $2\text{NS}_2 + 6\text{HO} = 2\text{NH}_3 + 3\text{S}_2\text{O}_2$. — (*Soubeyran*).

When aqua ammonia acts on chloride of sulphur, a variety of products are formed, among which is one, a white crystallizable solid, soluble in alcohol, which appears to consist chiefly of sulphur and nitrogen. Its nature is not yet ascertained, but it is distinguished by the property of dissolving in an alcoholic solution of potash with a deep purple color, which soon disappears, while ammonia is given off, and crystals of hyposulphide of potash are deposited. — (*W. G.*)

* As the compounds of the non-metallic elements with bases terminate in *ide*, it has lately become the custom to give the compounds of sulphur an analogous termination; therefore, sulphurets are now termed *sulphides*. Carburets, where it is necessary, might also be called *carbides*, phosphurets, *phosphides*, seleniurets, *seleniurides*, &c. French chemists, in particular, have pretty generally adopted the new nomenclature. Some of the first English and American chemists have also adopted it.

SULPHUR AND AMMONIA.

a. Protosulphide of Ammonium. $\text{NH}_4, \text{S} = \text{Am S} = 34.27$.

Syn. Hydrosulphide of Ammonia.—This compound is formed when 1 vol. of dry ammoniacal gas is mixed with $\frac{1}{2}$ vol. of sulphuretted hydrogen, $\text{NH}_3 + \text{H S} = \text{NH}_4, \text{S}$. It is best obtained by distilling a mixture of chloride of ammonium (sal ammoniac) and sulphide of barium, or of calcium. $\text{Ba S} + \text{NH}_4, \text{Cl} = \text{Ba Cl} + \text{NH}_4, \text{S}$. It forms colorless crystals, which are volatile, and dissolve readily in water. The solution becomes yellow by the gradual action of the atmospheric oxygen; it smells of sulphuretted hydrogen and ammonia: and in fact this solution may be more conveniently prepared by taking two equal portions of aqua ammoniac, and saturating one of them completely with sulphuretted hydrogen. This produces, first, sulphide of ammonium, and then a compound of that body with sulphuretted hydrogen, $\text{NH}_4, \text{S} + \text{H S}$. The other half of the aqua ammoniac is then added, and we have $(\text{NH}_4, \text{S} + \text{H S}) + \text{NH}_3 = 2 (\text{NH}_4, \text{S})$.

Sulphide of ammonium, or hydrosulphuret of ammonia, as it is called, is very much used as a test and re-agent in detecting and separating metals. It converts into sulphides many oxides on which sulphuretted hydrogen does not act, and it also dissolves many metallic sulphides.

The compound above mentioned, which is formed when ammonia is completely saturated with sulphuretted hydrogen, $\text{NH}_4, \text{S} + \text{H S}$, possesses very nearly the same properties, and may be used for the same purposes. It may be called the hydrosulphide of sulphide of ammonium.

Both the preceding compounds, when pure, are colorless; and their solution, mixed with acids, gives off sulphuretted hydrogen, without the deposition of sulphur. By keeping, however, they become yellow, and acids cause a precipitation of sulphur. This is owing to the formation of persulphide of ammonium.

b. Persulphide of Ammonium.

This compound is formed when either of the preceding is digested with sulphur. There seem to be several sulphides of ammonium, as of potassium, (which see), containing from 2 to 5 eqs. sulphur. When NH_4, S is exposed to the air, we may suppose the ammonium of 1 eq. to be oxidized (as is the case with potassium) and to be converted into free ammonia, $\text{NH}_4, \text{O} = \text{NH}_3, \text{H O}$, while the sulphur of that equivalent unites with the other, forming NH_4, S_2 . When the compound $\text{NH}_4, \text{S} + \text{H S}$ is exposed to the air, it is the hydrogen of the sulphuretted hydrogen which is oxidized, while its sulphur forms the bisulphide of ammonium. When sulphur is digested with either of the preceding compounds, different persulphides of ammonium are probably formed; and where

the sulphur is in excess, it yields, in all probability, the compound NH_4S_2 , analogous to persulphide of potassium, K_2S_2 .

All the yellow sulphides of ammonium have the same useful properties as the protosulphide in relation to metallic compounds, and some of them dissolve certain metallic sulphides still more readily. The persulphide of ammonium or sulphuretted hydrosulphide of ammonia, as it is sometimes called, is, therefore, very much used in analysis. It is distinguished from the protosulphide by the action of acids, which cause a precipitate of sulphur, and by its yellow or orange color. The solution of protosulphide of ammonium, when kept, becomes gradually yellow, from the formation of persulphide; so that, in fact, the latter is always present in the usual forms of this valuable re-agent.

Sulphide of ammonium, under the name of hydrosulphide of ammonia, is used in medicine. It ought to be given alone, in pure water, as it is decomposed by most acids or salts. The persulphide has long been known as Boyle's fuming liquor, which was obtained by distilling 3 parts of slaked lime, 2 of sal-ammoniac, and 1 of sulphur, into a receiver containing 3 parts of water. Thus prepared, it was an orange-colored liquid, of oily consistence, fuming in the air, and having a very offensive sulphurous smell. This preparation, however, contains variable proportions of free ammonia.

SULPHUR AND CHLORINE.

a. Dichloride of Sulphur. $\text{S}_2\text{Cl} = 67.71$.

Formed when chlorine is passed through a vessel containing flowers of sulphur, until nearly the whole sulphur has disappeared. The liquid formed is then purified by distillation. It is a reddish brown, fuming, pungent liquid, boiling at 280° . The Sp. G. of the liquid is 1.687; that of the vapor is 4.70. It is decomposed by water, yielding hydrochloric acid, hyposulphurous acid, and sulphur.

b. Protochloride of Sulphur. $\text{S Cl} = 51.59$.

When an excess of chlorine is passed through the preceding compound, and the liquid is repeatedly distilled at about 140° , the protochloride is obtained pure. It is a deep reddish brown liquid, which boils at 147° . Its Sp. G. is 1.62; that of its vapor, 3.68. When acted on by water, it yields hydrochloric acid and hyposulphurous acids, the latter being soon spontaneously decomposed, $2\text{S Cl} + 2\text{H O} = 2\text{H Cl} + \text{S}_2\text{O}_2$.

SULPHUR AND BROMINE.

Bromine combines readily with sulphur, and produces compounds analogous to the preceding.

SULPHUR AND IODINE.

When 1 part of sulphur and 8 of iodine are mixed and gently heated, they immediately combine and liquefy. On cooling, the liquid, which is dark brown, consolidates into a black crystalline solid, which is the iodide of sulphur. It must be kept in well-closed bottles, as it is destroyed by the access of air, iodine being given off. Its composition is probably SI . It is used in medicine as a remedy in various cutaneous diseases.

No compound of sulphur and fluorine is yet known.

9. SELENIUM. $Se = 39.6$.

This element occurs in very small quantity, chiefly in certain varieties of pyrites, the sulphur from which, when converted into sulphuric acid, leaves in the chambers a deposit, consisting of sulphur, selenium, and some metals; and from this the selenium is obtained. Some kinds of fuming sulphuric acid contains a little selenium, which separates on the addition of water as a red powder. Different processes are employed for extracting selenium from the deposit above mentioned; but the essential parts are, oxidizing and dissolving the selenium by means of aqua regia, separating the dissolved metals by sulphuretted hydrogen, &c., and finally deoxidizing the selenious acid by means of sulphite of ammonia and hydrochloric acid.

When precipitated, selenium appears as a red powder, which, when heated, melts, and on cooling forms a brittle mass, nearly black, but transmitting red light in thin plates. When more strongly heated it volatilizes, yielding a yellow gas, which condenses into a crystalline dark red powder on a cold surface.

Selenium is extremely analogous to sulphur, except in color; and this analogy is still more striking in its combinations. When heated in the air, it takes fire, burns with a blue flame, and produces a gaseous compound, oxide of selenium, SeO , which has a most penetrating and characteristic odor of putrid horse-radish. By this character selenium is easily recognized in minerals containing it, before the blowpipe.

SELENIUM AND OXYGEN.

These elements combine in three proportions:

a. Oxide of Selenium. $SeO = 47.613$.

This compound has been already mentioned. It is formed when selenium burns, and is gaseous; it is not acid, and has no analogy with any of the oxides of sulphur.

b. Selenious Acid. $SeO_3 = 55.626$.

This acid is formed when selenium is dissolved in nitric acid, and the solution evaporated to dryness. It is a solid which, when

heated, is converted into a yellow gas, condensing again into acicular crystals. It is very soluble in water, and has an acid taste. In composition it corresponds to sulphurous acid. This latter acid and its salts deprive selenious acid and its salts of oxygen, causing selenium to be deposited in the uncombined state.

c. Selenic Acid. $\text{H O, Se O}_2 = \text{H, Se O}_4 = 72.652$.

This acid is formed when selenium is oxidized by fusion with nitre. The fused mass is dissolved in water, and the selenic acid precipitated as seleniate of lead by adding a salt of lead. The seleniate of lead is decomposed by sulphuretted hydrogen, and the filtered solution of selenic acid cautiously evaporated till it has the Sp. G. 2.625. It is now hydrated selenic acid, H O, Se O_2 , or rather H, Se O_4 . It is very acid and corrosive, and resembles sulphuric acid very much. It may be recognized by the action of hydrochloric acid, which reduces it to selenious acid, chlorine being set free. Selenic acid is not decomposed by sulphurous acid (as selenious acid is), or by sulphuretted hydrogen. It produces intense heat when mixed with water.

With bases, for which it has great affinity, selenic acid forms salts, called seleniates, which are isomorphous with the corresponding sulphates, and entirely resemble them in external characters.

SELENIUM AND HYDROGEN.

Seleniuretted Hydrogen. $\text{H Se} = 40.6$.

SYN. Hydroselenic Acid. — This compound is obtained, like sulphuretted hydrogen, which it much resembles, by the action of acids on metallic seleniurides. $\text{M Se} + \text{H Cl} = \text{M Cl} + \text{H Se}$.

It is a colorless gas, which is combustible, and when burned gives off the characteristic odor of oxide of selenium. Seleniuretted hydrogen itself has a smell resembling that of sulphuretted hydrogen, and when respired is even more poisonous than that gas. A small bubble of it produces much and painful irritation of the mucous membrane of the nose and eyes; and if it reaches the bronchi, excites severe cough, in addition to its poisonous action if absorbed into the blood. The presence of a small quantity of it in sulphuretted hydrogen seems to exalt the poisonous energy of the latter. Like sulphuretted hydrogen, this gas is absorbed by water, and precipitates most metallic solutions, yielding seleniurides corresponding to the respective oxides. Most of these seleniurides are black or dark brown; but those of zinc, manganese, and cerium, are flesh red.

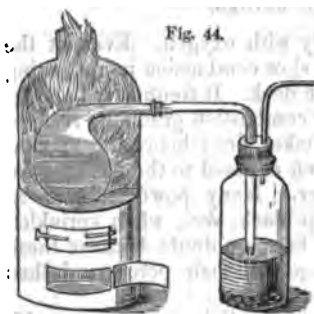
Nothing is known of the compounds of selenium with nitrogen. With ammonia it is probable that seleniuretted hydrogen forms seleniuride of ammonium, $\text{N H}_4, \text{Se}$, and hydroseleniuride of seleniuride of ammonium, $\text{N H}_4, \text{Se} + \text{H Se}$. — (*Bisnau.*)

Chloride of selenium appears to be analogous to chloride of sulphur; and the same may be said of the bromide and iodide.

10. PHOSPHORUS. $P = 31.14$.

This element occurs abundantly in the bones of animals, in combination with oxygen and metals, as phosphate of lime, phosphate of magnesia, &c. It is also an ingredient in some unknown form of combination, of vegetable and animal fibrine and albumen; and is constantly present in the urine and excrements. In the mineral kingdom it occurs as phosphate of lime (apatite), phosphate of alumina (wavellite), phosphates of lead, copper, &c.

To obtain phosphorus pure, 10 parts of burnt bones are mixed with 30 or 40 parts of water, and 6 parts of oil of vitriol gradually added. After 24 hours, 50 or 60 parts of water are added to the mixture, and the whole well stirred and digested for a day or two. The strained liquid is evaporated to the consistence of thick syrup, and is then acid phosphate of lime. It is now mixed with $\frac{1}{4}$ of its weight of powdered charcoal, dried up, and gently ignited.



The mass is then gradually heated to whiteness in a stoneware or iron retort, the neck of which ends in a wide bent tube, which dips a little under water. Half of the phosphoric acid in the acid phosphate of lime is deoxidized by the charcoal, and phosphorus is set free, which distils over and condenses under the water. Owing to the presence of water in the mass, part of the phosphorus is disengaged in combination with hydrogen, forming a

spontaneously combustible gas. Care must therefore be taken to avoid explosions. The action of the charcoal on the phosphoric acid is thus represented: $PO_3 + C = 5CO + P$. Carbonic oxide gas, CO , is therefore disengaged in large quantity.

The phosphorus is now to be melted under water, and squeezed through chamois leather, which separates impurities. It is lastly melted under water, in funnels with long cylindrical necks, stopped below. Into the necks of the funnels the phosphorus runs, and when cold may be pushed out in the form of solid cylinders.

Pure phosphorus is a colorless, or very pale, yellowish, transparent, or translucent solid, of the consistence of wax. Its Sp. G. is 1.77. At 113° it melts, and at 572° it boils, distilling completely in close vessels. It has, in the solid form, neither taste nor smell; but it gives off vapors in the air, which undergoing a slow combustion, have an odor of garlic; and in solution it has an

acid disagreeable taste. Phosphorus is insoluble in water; soluble in alcohol, ether, oils, sulphide of carbon, and chloride of phosphorus. From the latter liquids it is often deposited in octohedral and dodecahedral crystals. It is very poisonous, but is used in medicine in very small doses.

When kept in vessels exposed to light, phosphorus becomes yellow, or even brown, externally, owing to some unexplained change. It must always be kept under water, and never taken into the fingers, for it is so combustible as occasionally to take fire from contact with the warm hand, where, as it melts and continues to burn, it inflicts frightful injuries.

When heated in air, phosphorus takes fire, and burns with a bright light, producing much white smoke, which is anhydrous phosphorous acid, P O_2 . When heated in oxygen, it burns with a light so dazzling that the eye cannot endure it. In contact with chlorine, bromine, or iodine, without the aid of heat, combustion takes place spontaneously, while the phosphorus combines with these metalloids.

PHOSPHORUS AND OXYGEN.

Phosphorus combines very readily with oxygen. Even at the ordinary temperature it undergoes a slow combustion in air, giving out vapors which are luminous in the dark. It frequently happens that the heat developed by this slow combustion gradually reaches the point at which the phosphorus takes fire: hence the spontaneous combustion of phosphorus, if left exposed to the air, and the necessity of keeping it under water. Many powders, such as powder of platinum, charcoal, lamp-black, &c., when sprinkled on dry phosphorus, cause it to take fire; no doubt because these powders absorb and condense oxygen in their pores, and thus bring it into close contact with the phosphorus.

Many different kinds of instantaneous lights are made with phosphorus, owing to its ready combustibility by friction, especially when chlorate of potash is used.

We are acquainted with four compounds of phosphorus and oxygen.

a. Oxide of Phosphorus. $\text{P}_2 \text{O}_2 = 86.28$.

This oxide is obtained by causing a current of oxygen to come in contact with phosphorus under boiling water. Combustion takes place, and some phosphoric acid is formed; but a part of the phosphorus forms an insoluble cinnabar red powder, which is oxide of phosphorus, $\text{P}_2 \text{O}$.

It burns, if heated nearly to redness, in the air: if heated in close vessels, it is resolved into phosphorous and phosphoric acid, $5\text{P}_2 \text{O}_2 = 2\text{P O}_2 + \text{P}_2$. It is oxidized with combustion by nitric acid, and takes fire in chlorine gas.

b. Hypophosphorous Acid. $\text{P O} = 55.14$.

In the separate, or hydrated state, P O , 3 H O , or P O_4 , H_3 . This acid is formed when phosphides of the alkaline metals act on water, or when phosphorus is boiled with alcalies and water, phosphoric acid and phosphuretted hydrogen gas being formed at the same time. The two acids combine with the base; and if this be lime or baryta, the hypophosphite being soluble, is easily separated from the insoluble phosphate. From the hypophosphite of baryta, sulphuric acid removes the baryta, and the hypophosphorous acid is left, dissolved in water. By gentle evaporation it may be obtained as a deliquescent crystalline mass, which is the hydrated acid.

When heated in close vessels, this acid is resolved into phosphuretted hydrogen gas and phosphoric acid. Thus: $2 (\text{P O}, 3 \text{ H O}) = \text{P H}_3 + \text{P O}_5, 3 \text{ H O}$. It is a powerful deoxidizing agent, taking oxygen from many other substances, and passing into phosphoric acid. With bases it forms salts called hypophosphites, which are all soluble in water, and which, when heated, are resolved into phosphates and phosphuretted hydrogen.

c. Phosphorous Acid.

In the anhydrous state, P O_3 ; in the separate, or hydrated, state, (the crystals,) $\text{P O}_3, 3 \text{ H O}$, or $\text{P O}_5, \text{H}_3$.

This acid is formed, along with phosphoric acid, during the slow combustion of phosphorus in air. It is best obtained pure by acting on the sesquichloride of phosphorus, P Cl_3 , by water. $\text{P Cl}_3 + 6 \text{ H O} = 3 \text{ H Cl} + \text{P O}_3, 3 \text{ H O}$. The hydrochloric acid is easily expelled by a gentle heat, and the aqueous solution of phosphorous acid, if sufficiently evaporated, yields a mass composed of deliquescent crystals. This is the hydrated acid.

This acid, like the preceding, is a powerful deoxidizing agent. When heated in close vessels, the anhydrous acid, obtained by the combustion of phosphorus in rarefied air, yields phosphorus, and anhydrous and phosphoric acid, $5 \text{ P O}_3 = 3 \text{ P O}_5 + \text{P}_2$. The hydrated acid, in the same circumstances, yields hydrated phosphoric acid and phosphuretted hydrogen gas, $4 (\text{P O}_3, 3 \text{ H O}) = 3 (\text{P O}_5, 3 \text{ H O}) + \text{P H}_3$.

With bases phosphorous acid forms salts, which are called phosphites; and the general formula of the neutral phosphites is, $\text{P O}_3, 3 \text{ M O}$, or $\text{P O}_5, \text{M}_3$.

d. Phosphoric Acid.

1. Anhydrous Phosphoric Acid. $\text{P O}_5 = 71.465$.

This compound is formed only when phosphorus is burned in dry air or oxygen gas. It then appears as a white solid, like snow, which rapidly attracts moisture from the air, and passes

into metaphosphoric acid, $P O_5, H O$, or $P O_5, H$; and this again soon changes, in contact with water, especially if heated into common or hydrated phosphoric acid, $P O_5, 3 H O$, or $P O_5, H_3$. The anhydrous phosphoric acid, like the anhydrous sulphuric acid, can hardly be said to be an acid body, as it does not exhibit acid properties until it has been brought into contact with water.

2. Hydrated Phosphoric Acid.

There are three different acids to which this name may be given. If we view them as compounds containing water, then they all contain anhydrous phosphoric acid, combined in each with a different proportion of water, and their formulæ will be $P O_5, H O$; $P O_5, 2 H O$; and $P O_5, 3 H O$. If, on the other hand, we view them as hydrogen acids, then they contain no anhydrous phosphoric acid, but are quite distinct compounds, and their formulæ will be as follows: $P O_5, H$; $P O_7, H_3$; and $P O_9, H_5$. The latter view is much more probable, and agrees better with the properties and composition of these acids, and of their salts. The first is called metaphosphoric acid, the second pyrophosphoric acid, and the third common phosphoric acid; or they may be still better designated as monobasic, bibasic, and tribasic phosphoric acids.

METAPHOSPHORIC, OR MONOBASIC PHOSPHORIC ACID.



This acid is easily obtained by dissolving phosphorus in diluted nitric acid with the aid of heat, evaporating to a syrup, and exposing the residue to a red-heat in a platinum crucible. Or the solution of the anhydrous acid may be treated in the same manner; or phosphate of ammonia may be ignited in a platinum crucible. When phosphoric acid has once come in contact with water, it can never be rendered anhydrous by heat; it can only be reduced to the state of monobasic acid.

As thus obtained, it appears in the shape of a colorless and transparent glass, which slowly dissolves in water. It is hence called glacial phosphoric acid. Its solution causes in solutions of silver a white granular precipitate of monobasic phosphate of silver; it also coagulates albumen. But if long kept, or if very rapidly boiled, this solution passes into one of tribasic phosphoric acid, and no longer precipitates silver or coagulates albumen. Here 2 eqs. of water enter into the composition of the acid: $P O_5, H O + 2 H O = P O_5, 3 H O$.

With bases this acid forms one series of salts, the monobasic phosphates, the general formula of which is, $P O_5, M O$, or $P O_5, M$. In these, the hydrogen of the acid is replaced by its equivalent of metal. The precipitate caused by the acid in solutions of silver is one of these salts: $P O_5, A g O$.

PYROPHOSPHORIC, OR BIBASIC PHOSPHORIC ACID.

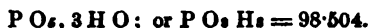


When common or tribasic phosphoric acid, $\text{P O}_5, 3 \text{ H O}$, is heated for some time to 417° , it loses one-third of the water it contains, and becomes bibasic, or pyrophosphoric acid. It appears as a viscid syrup, very acid and very soluble in water. Its solution neither precipitates silver nor coagulates albumen; but if previously neutralized by ammonia, it causes in salts of silver a flaky white precipitate of bibasic phosphate of silver, $\text{P O}_5, 2 \text{ Ag O}$. The solution of this acid, like that of the preceding, soon passes into tribasic acid, especially if heated.

With bases it forms two series of salts, one containing 2 eqs. of base, the other 1 eq. of base, and 1 of water. The former are neutral, and have the general formula, $\text{P O}_5, 2 \text{ M O}$: the latter are acid, and their formula is, $\text{P O}_5, \text{ M O}, \text{ H O}$. This acid is much more easily obtained in combination with a base than in the free state, and in fact it was discovered in the salt obtained by igniting the common phosphate of soda, when there is left pyrophosphate or bibasic phosphate of soda, $\text{P O}_5, 2 \text{ Na O}$.

When a pyrophosphate is melted with excess of base, it is converted into a tribasic phosphate. Thus, if pyrophosphate of soda be fused with an additional equivalent of soda, the tribasic salt, $\text{P O}_5, 3 \text{ Na O}$, is formed, which no longer contains pyrophosphoric acid.

COMMON, OR TRIBASIC PHOSPHORIC ACID.



When a solution of any of the preceding acids is evaporated by a moderate heat to the consistence of syrup, the residue is found to be the tribasic acid, $\text{P O}_5, 3 \text{ H O}$. Heated for a long time to 417° , it loses 1 eq. water and becomes bibasic; heated to redness, it gives off 2 eqs. water, and becomes monobasic. A diluted solution of either of these gradually becomes tribasic, and this change is very rapidly effected by boiling. Solution of common phosphoric acid neither precipitates silver nor coagulates albumen; but if neutralized by ammonia, it causes in salts of silver a pale yellow precipitate of tribasic phosphate of silver, $\text{P O}_5, 3 \text{ Ag O}$.

The most economical method of preparing phosphoric acid is to add to the syrupy superphosphate, or acid phosphate of lime, previously described, oil of vitriol as long as it causes a precipitation of sulphate of lime. The mixture becomes quite thick, and is to be diluted with water, filtered, again concentrated to a syrup, and again tested by adding a few drops of oil of vitriol. When no more sulphate of lime is formed, the solution is free from lime, but still contains phosphate of magnesia. It is to be evaporated and gradually heated to redness in a platinum vessel, by which means all the excess of sulphuric acid is expelled, and a glass is

left. To separate the magnesia, this glass is to be dissolved in warm water, and the solution evaporated in a platinum dish till its temperature reaches 600° F., and phosphoric acid begins to be expelled along with the water. At this point the thick viscid mass becomes turbid, from the separation of insoluble phosphate of magnesia; and if the same temperature is kept up for a quarter or half an hour, the whole of the magnesia assumes the insoluble form. Water being now added, the pure phosphoric acid dissolves, the insoluble phosphate of magnesia is separated by filtration, and the filtered liquid is a pure solution of phosphoric acid. It is now evaporated and once more gently ignited in a covered platinum vessel. Pure monobasic phosphoric acid is left. It is now dissolved in hot water, and becomes tribasic acid, the form usually employed, as it is the most permanent. Like the other phosphoric acids, it is very acid, but not corrosive. It is occasionally used in medicine.

With bases, common phosphoric acid forms three series of salts, in which the 3 equivalents of water in the acid are wholly or partially replaced by metallic oxides. Thus, with soda it forms three salts; 1st, neutral phosphate, $\text{P O}_5, 3 \text{ Na O}$; 2nd, common phosphate of soda, $\text{P O}_5, 2 \text{ Na O, H O}$; 3rd, acid phosphate of soda, $\text{P O}_5, \text{Na O, 2 H O}$. In each of these salts there are 3 eqs. of base, but these may be either all soda, or partly soda and partly basic water. All three salts give with the salts of silver the same yellow precipitate, $\text{P O}_5, 3 \text{ Ag O}$; but the supernatant liquid is only neutral when the neutral phosphate is used; it is acid in the case of the other two salts, because, for every eq. of oxide of silver in the precipitate, 1 eq. of nitric acid has to be neutralized, and this cannot be effected by the basic water, but only by the soda.

When the second or common phosphate of soda is ignited, its basic water is driven off, and bibasic phosphate of soda, $\text{P O}_5, 2 \text{ Na O}$, is left. This salt, dissolved in water, gives with salts of silver a white flaky precipitate of bibasic phosphate, while the supernatant liquid remains neutral.

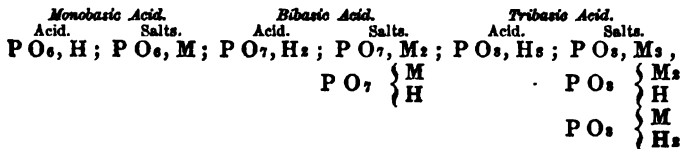
If the third or acid phosphate of soda be ignited, it loses 2 eqs. of basic water, and monobasic phosphate is left, which, if dissolved in water, gives with silver a granular white precipitate of monobasic phosphate, the supernatant liquid remaining neutral.

From the above brief description of the three modifications of phosphoric acid, it will be seen that their characters are distinct and well marked. Graham views them, according to the formulae which assume the presence of water, as three different hydrates of the same anhydrous acid; and he considers that when the anhydrous acid has combined with one, two, or three atoms of water, it acquires and retains, in each case, the power or tendency to combine with one, two, or three equivalents of fixed base. The

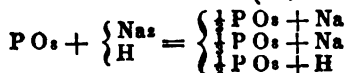
facility with which one form passes into the other is in favor of this view; but it must be observed that it affords no explanation of the remarkable tendency alluded to, but only states the fact, and still leaves unanswered the question, Why does anhydrous phosphoric acid at one time unite with 1 eq., at another with 2 eqs. or 3 eqs. of water? or why does it, by doing so, acquire the tendency to unite with 1, 2, or 3 eqs. of base?

Liebig, on the other hand, considers the three acids as radically different, being formed of hydrogen, united in each to a different compound radical; and that as in the first there is only 1 eq., in the second 2 eqs., and in the third 3 eqs. of hydrogen, the salts must necessarily contain equivalent proportions of metals which, in the two latter, may replace the hydrogen either wholly or partially, as in other polybasic acids. The formula for the acids, on this view, have been given above.

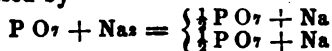
The now admitted existence of numerous polybasic acids, and the growing tendency to consider all hydrated acids as hydrogen acids, tend to induce us to prefer the latter view, which moreover has the advantage of at least offering an explanation of the different neutralizing power of the three acids, which is referred to the amount of replaceable hydrogen they contain. Thus we have—



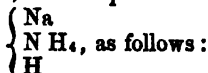
If we begin from the tribasic acid, and represent one of its salts, the common phosphate of soda, $\text{P O}_9, \begin{Bmatrix} \text{Na}_3 \\ \text{H} \end{Bmatrix}$, as follows:

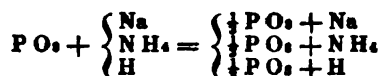


We see that when this salt is ignited, 1 eq. of hydrogen is expelled, along with 1 eq. of oxygen, and the 2 eqs. of sodium now neutralize the whole of the remaining phosphorus and oxygen, which is $\frac{2}{3} \text{P O}_9 - \text{O} = \text{P O}_7$, and the bibasic salt, $\text{P O}_7, \text{Na}_2$ results. If this be expressed by



We see that something has been added to the radical previously united with each eq. of sodium, without altering its neutralizing power. In like manner, if we represent microcosmic salt, $\text{P O}_8,$





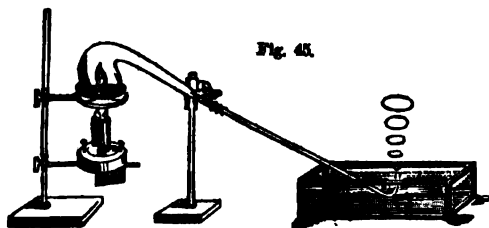
We see that when it is ignited, the hydrogen and the ammonium are both expelled, each combined with 1 eq. of oxygen; but as the rest of the phosphorus and oxygen formerly combined with them is not expelled, it enters into the composition of the radical still united with the 1 eq. of sodium, but without affecting its neutralizing power. This radical, therefore, becomes $\frac{1}{2} \text{P O}_2 - \text{O}_2 = \text{P O}_2$; and its salt with sodium is $\text{P O}_2, \text{Na}$, the monobasic phosphate of soda. If, now, we turn to what was said above of the acids of sulphur, viewed as hydrogen acids, we shall there see many analogous cases of the addition to the acid radical of different quantities of its elements, while the neutralizing power remains unchanged. Thus, hydrated sulphurous acid, $\text{H} + \text{S O}_2$, by the addition of $\text{S O}_2 + \text{S}_2$ to its radical, becomes the acid of Fordos and Gelis, without change of neutralizing power. In the phosphoric acids, the neutralizing power varies, because the hydrogen varies: but when they are represented, as has been done above, in such a way as to keep the hydrogen (or metal) the same in all, the analogy between them and the acids of sulphur, in regard to the non-dependence of the neutralizing power on the nature and proportions of the ingredients of the radical, becomes manifest.

The above is the view which Liebig takes of the nature and formation of the three phosphoric acids. It must be admitted, that it has the advantage of simplicity; that it explains, in a consistent manner, all the known facts; and that it is at present better supported, and rests on fewer assumptions, than any other theory of the constitution either of these acids, or of acids in general.

PHOSPHORUS AND HYDROGEN.

Phosphuretted Hydrogen. $\text{P H}_2 = 34.4$.

This compound may be formed by the action of phosphurets of alkaline metals on water, or by the action of phosphorus on boiling alkaline solutions. Thus, phosphide of calcium, thrown into water, disengages the gas in question; and it is also produced in



large quantity by applying heat to a mixture of lime, water, and fragments of phosphorus, in a retort nearly filled with the mixture, or by boiling phosphorus with an alcoholic solution of potash. The two former methods yield it in a form in which it is spontaneously combustible on coming in contact with air or oxygen; the latter in a form in which it requires the contact of flame in order to burn. The gas in both cases is essentially the same; but in the former it contains a minute proportion of a compound, not yet isolated, which is spontaneously inflammable, and which, inflaming by contact of air, kindles the gas. This compound is supposed to be PH_2 . When the spontaneously inflammable gas is long kept, it deposits a solid compound, PH , and is then no longer spontaneously combustible. Possibly 2PH_2 yield PH and PH_2 .

The gas, whether spontaneously inflammable or not, is colorless, and has a very offensive smell of putrid fish. When it burns, it produces anhydrous phosphoric acid and water, forming thick white vapors; and when bubbles of the spontaneously inflammable gas take fire in still air, they form beautiful circular wreaths of vapor, which ascend, gradually widening, till they are dissipated in the air.

The addition of ether, oil of turpentine, and many other substances, destroys the spontaneous inflammability; but this property may be restored by adding to the gas a minute proportion of nitrous acid. — (*Graham*.)

Phosphuretted hydrogen is neither acid nor alkaline; but it seems to have alkaline tendencies, since it combines with hydriodic acid, forming a neutral crystalline compound, isomorphous with hydriodate of ammonia. It also combines with several metallic chlorides, forming compounds analogous to those produced by ammonia with the same chlorides. Rose, who has described these compounds, points out a considerable analogy between phosphuretted hydrogen and ammonia.

It has already been mentioned, that when hypophosphorous and phosphorous acids are heated, they are resolved into phosphoric acid and phosphuretted hydrogen. This gas is consequently given off frequently toward the end of the evaporation of a solution of phosphorus in diluted nitric acid, which at first forms phosphorous acid, by the decomposition of which the gas is produced, causing a sudden combustion at the surface of the evaporating liquid.

Since the above account was printed, M. P. Thénard has published an elaborate memoir on phosphuretted hydrogen, from which it appears that there exist, — 1st, a fluid compound PH_2 , or $5\text{PH}_2 = \text{P}_2\text{H}_{10}$; 2nd, a solid compound P_4H ; and 3rd, the gas P_2H_2 . The fluid is first formed, and is then spontaneously or very easily resolved into the other two. Thus:



The gas, PH_3 , acquires its spontaneous combustibility by dissolving some of the liquid PH_3 or P_2H_4 . In fact this liquid communicates the same property to other gases.

PHOSPHORUS AND NITROGEN.

Phosphide of Nitrogen. $\text{NP} = 45.52$.

This is a white insoluble powder, formed by the action of ammonia on sesquichloride of phosphorus. $\text{NH}_3 + \text{P}_2\text{Cl}_3 = 3\text{HCl} + \text{NP}_2$. It is infusible and fixed in the fire in close vessels.

PHOSPHORUS AND CHLORINE.

Phosphorus takes fire spontaneously in chlorine gas, forming two compounds.

Trichloride of Phosphorus. $\text{PCl}_3 = 137.81$.

When phosphorus is made to pass, in the form of vapor, through a tube filled with coarse powder of bichloride of mercury, HgCl_2 , or when chlorine is slowly passed through a tube or retort containing phosphorus, a volatile colorless liquid is obtained, which is sesquichloride of phosphorus: $3\text{HgCl}_2 + \text{P} = 3\text{HgCl} + \text{PCl}_3$. Here protochloride of mercury is left, while the excess of chlorine combines with the phosphorus. The sesquichloride is a pungent fuming liquid, which, in contact with water, yields hydrochloric and phosphorous acids. $\text{PCl}_3 + 3\text{H}_2\text{O} = 3\text{HCl} + \text{P}_2\text{O}_3$.

b. Perchloride of Phosphorus. $\text{PCl}_5 = 308.75$.

This compound is best formed by passing a current of chlorine through the preceding to saturation. It is a white volatile solid, of a pungent smell. In contact with water, it yields hydrochloric and phosphoric acids: $\text{PCl}_5 + 5\text{H}_2\text{O} = 5\text{HCl} + \text{P}_2\text{O}_5$.

PHOSPHORUS AND BROMINE. — PHOSPHORUS AND IODINE.

With these elements phosphorus also unites with spontaneous combustion, and forms with each two compounds, analogous to those with chlorine. They are volatile solids, yellow in the case of bromine; dark brown or nearly black in the case of iodine. They decompose water like the chloride, with the production of hydrobromic and hydriodic acids on the one hand, and phosphorus or phosphoric acids on the other.*

* M. Corenwinder has lately prepared several definite and crystalline compounds of iodine and phosphorus. He produces them by successively dissolving the phosphorus and iodine in sulphide of carbon, and cooling the solutions.

The *Biniodide of Phosphorus* (PI_2) crystallizes in large orange-red prisms. They fuse at 110° , change in the air, and volatilize at a high temperature.

The *Teriodide of Phosphorus* gives large irregular crystals of a fine red color, consisting apparently of hexagonal plates; which, when distilled, give a mass which by fusion yields prismatic crystals. They fuse at 55°C ., and are decomposed by water, with evolution of hydriodic acid (HI).

PHOSPHORUS AND SULPHUR.

When phosphorus and sulphur are heated together under water they combine, often with incandescence, forming several compounds, which are exceedingly inflammable, and having a tendency to explode violently when heated, from some unknown cause, are very dangerous to experiment with. Berzelius has lately examined these compounds, and has described the following:

1st. $P_2 S$. This compound occurs in two states, as a colorless liquid, and as a red powder.

2nd. PS . A pale yellow liquid, also as an orange powder.

3rd. PS_2 . Yellow crystals.

4th. $P_2 S_2 = P_2 S + PS$. A scarlet powder, changed by distillation into a liquid.

5th. PS_3 . A yellow fusible solid.

6th. PS_4 . A yellow chrystallizable solid.

It is very remarkable, that several of these compounds occur in two distinct states; and Berzelius conceives that this is owing to the circumstance that, like sulphur, phosphorus itself exists in two mechanically distinct states, and that the difference of the two states of the compounds depends on the one containing phosphorus in its ordinary condition, while in the other the phosphorus is in the allotropic state, as it is now called.

In the above section, we have considered the atom of phosphorus to be 15.7, on which view most of the compounds of phosphorus must contain 2 atoms and 1 equivalent. Thus phosphoric acid is $P_2 O_5$; phosphorous acid, $P_2 O_3$; phosphuretted hydrogen, $P_2 H_2$; the chlorides of phosphorus, $P_2 Cl_3$, and $P_2 Cl_4$. But since that section was first printed, the Continental chemists have, for the most part, adopted the equivalent of hydrogen generally admitted in this country, as well as the view, according to which atom and equivalent are synonymous, or at least convertible terms. It is on this account that they now admit our atomic weight of hydrogen: and to be consistent we should apply the same rule to phosphorus, which, as we have seen, enters into combination nearly if not altogether uniformly, in the proportion of two atoms. In fact, we do admit the equivalent of phosphorus to be 31.4. Now it appears to me that we ought to call this, not only one equivalent, but also one atom. In that case, phosphoric acid will be PO_5 ; phosphorous acid, PO_3 ; phosphuretted hydrogen, liquid PH_2 , solid $P_2 H$, and gaseous $P H_2$; and the chlorides of phosphorus, $P Cl_3$, and $P Cl_4$.

- When two equivalents of phosphorus and five equivalents of iodine are employed, at first there are obtained crystals of PI_2 , and then those of PI_3 . M. Corenwinder also, by using the sulphide of carbon as a solvent, obtained crystals of several other compounds, such as the perchloride and sulphide of phosphorus. S.

The same change ought to be adopted in the case of arsenic, the atom of which, instead of 37.7, ought to be 75.4; and the formulæ of arsenious and arsenic acids, instead of $As_2 O_3$, and $As_2 O_5$, will be $As O_3$, and $As O_5$.

It is possible that some other atomic weights will have to be doubled in the same way. Those of iron and chromium, however, although these elements form compounds such as $Fe_2 O_3$, $Fe_2 Cl_3$, $Cr_2 O_3$, $Cr_2 Cl_3$, &c., &c., do not require this change, because these metals also form compounds such as $Fe O$, $Fe Cl$, $Fe S$, $Cr O$, &c., &c.

11. CARBON. $C=6.04$.

This element occurs very abundantly in nature, generally combined. In the pure state, and crystallized, it constitutes the diamond. In a compact, amorphous condition, it occurs as plumbago or graphite; and in a much less pure form, as anthracite coal. It is an essential ingredient of all organized tissues and products, animal and vegetable; and it is also found in the mineral kingdom as the chief component of pit coal and wood coal, which are evidently derived from vegetables; and further as carburetted hydrogen gas, the fire-damp, and carbonic acid gas, the choke-damp of coal mines, which are products of the decay of vegetable matter.

Carbonic acid is abundant in volcanic districts and in mineral waters, and, combined with lime or magnesia, constitutes extensive rock formations.

Carbonate of lime occurs, for example, as marble, limestone, and chalk; and along with carbonate of magnesia, as dolomite. When crystallized, it forms calcareous spar.

Carbonate of magnesia also forms rocks in some parts of the world.

In smaller quantity, the carbonates of baryta, strontia, lead, and some other bases, are also found.

Carbonic acid gas is always present in the atmosphere, of which it forms about $\frac{1}{1000}$ by weight.

Carbon is artificially prepared by heating organic matter in close vessels as long as any volatile substances are given off. These volatile bodies are compounds of carbon, hydrogen, nitrogen, and oxygen, in various proportions, and the residue is the excess of carbon, which is fixed in the fire, provided oxygen be excluded. Wood thus treated yields common charcoal, which is carbon + the ashes or mineral elements of the wood. Coal yields coke, which is more dense in its structure. Animal matters yield animal charcoal, which contains phosphates, and also nitrogen, probably as mellone, $C_2 N_4$. The charcoal from bones is called bone or ivory-black, and is of course loaded with phosphate of lime. When oils or resins, which are always rich in carbon, are burned

with a deficient supply of oxygen, they yield a great deal of soot, which is called lamp-black. When ignited in close vessels, to expel any traces of oil or volatile matters, it is almost pure carbon.

The diamond, or crystallized carbon, is the hardest body known. Its Sp. G. is 3.5. It is also quite infusible, but is easily burned when heated in oxygen, and is converted into carbonic acid. It is remarkable for its transparency and high refractive and dispersive power; it is a non-conductor of electricity. In the other (allotropic?) form of graphite anthracite or charcoal, carbon is opaque, black, combustible in air or oxygen, yielding carbonic acid, but is now a conductor of electricity. Its Sp. G. is 2. In all its forms, carbon is devoid of taste or smell, insoluble, as such, in all menstrua (although it may be oxidized and dissolved as carbonic acid by strong nitric acid, or aqua regia, with the aid of heat), and altogether fixed in the fire in close vessels.

In open vessels, carbon, when heated, takes fire, and, if pure, burns entirely away, being converted into carbonic acid gas. Indeed, the attraction of carbon for oxygen at a red-heat, exceeds that of almost all other bodies. It is to this property, and to the heat and light given out in its combustion, that are owing the uses of carbon, as the chief ingredient of all kinds of fuel, whether burned for heat or for light.

CARBON AND OXYGEN.

With oxygen, carbon forms two well-marked gaseous compounds, which shall be here described. The same elements, in other proportions, constitute, according to the opinion which regards oxygen acids as hydrates, certain anhydrous acids, to be described under the head of organic chemistry. As these anhydrous acids, however, are not known in the separate form, we may rather consider the acids in question (the oxalic, mellitic, croconic, and rhodizonic acids) as compounds of hydrogen.

a. Carbonic Oxide. $\text{CO} = 14.053$.

This gas is formed either when carbon is burned with a limited supply of air, as when air is passed through a mass of red-hot charcoal; or when carbonic acid is brought into contact with red-hot charcoal. In the latter case, the carbonic acid, CO_2 , is reoxidized, while the carbon is oxidized, $\text{CO}_2 + \text{C} = 2\text{CO}$.

It is best obtained by heating in a retort 1 part of finely-powdered ferrocyanide of potassium (prussiate of potash) along with 10 parts of oil of vitriol. The salt contains cyanide of potassium, $\text{K}_2\text{C}_2\text{N}_4$, and cyanide of iron, $\text{Fe}_2\text{C}_2\text{N}_4$. One or both of these salts acts on the sulphuric acid and water, yielding sulphate of potash (or of iron), sulphate of ammonia, and carbonic oxide:

$K, C_2N + 2(HO, SO_3) + 2HO = (KO, SO_3) + (NH_4O, SO_3) + 2CO$. The gas may also be obtained by heating a mixture of a formiate, MO, C_2HO_3 , with an excess of oil of vitriol, $MO, C_2HO_3 + HO, SO_3 = MO, SO_3 + 2HO + 2CO$. When oxalic acid, HO, C_2O_3 , or an oxalate, MO, C_2O_3 , is heated with an excess of oil of vitriol, there is obtained a mixture of carbonic oxide and carbonic acid gases: $MO, C_2O_3 + HO, SO_3 = MO, SO_3 + HO + CO + CO_2$. By passing the mixed gases through milk of lime or solution of potash, the carbonic acid is arrested, and the carbonic oxide gas obtained pure.

Carbonic oxide gas may be collected and kept over water. It is transparent and colorless, has neither taste nor smell, and when respired is fatal to animal life. It takes fire when heated to redness in contact with air, as by the approach of a candle, and burns with a lambent, clear blue flame, combining with a second equivalent of oxygen, and yielding carbonic acid. Its Sp. G. is 0.9722. The blue flame that is often seen to play on the surface of a large red-hot coal fire is owing to the formation of this gas; the carbonic acid formed at the lower part of the fire being forced to pass through a thick mass of red-hot charcoal. The formation of this poisonous gas is also one cause of the danger of slowly burning charcoal in chauffers, in rooms where there is no chimney and little ventilation.

Carbonic oxide is a compound radical; that is, it acts like an element, combining with elements. Thus, it combines with chlorine, with oxygen, with metals. In this point of view it is a most interesting compound; but, like cyanogen, comes to be treated of as a compound radical in the organic division of the work.

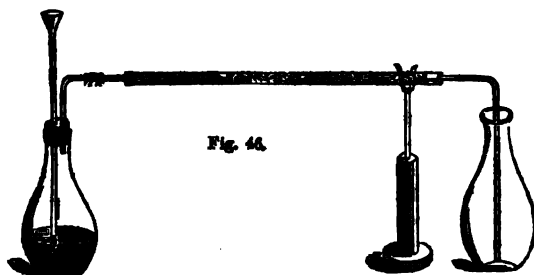
b. Carbonic Acid. $CO_2 = 22$.

Srx. Fixed Air.—This gas occurs in a variety of circumstances which have been noticed above, in treating of carbon. In addition to these, it may here be mentioned that it is formed during the respiration of animals, and that it is a chief product of the vinous or alcoholic fermentation. It is also formed in large quantity in all ordinary combustions, from the oxidation of the carbon in the fuel.

It is best prepared artificially by the action of diluted hydrochloric or sulphuric acid on marble or chalk, which, as already stated, is carbonate of lime, CaO, CO_2 . Thus we have $CaO, CO_2 + HCl = CaCl + HO + CO_2$. It may be collected with some loss, over water, which absorbs it to a considerable extent.

It is a transparent and colorless gas, with rather a pungent sub-acid smell, and a slight acidulous taste. Its Sp. G. is 1.527 and it is so much heavier than air, that it may be collected in

vessels by displacement, as represented in the cut, especially if it be wanted dry, after passing through a tube filled with chloride of



calcium. Lime-water is rendered turbid by this gas, the insoluble carbonate of lime being formed; and by this character it is distinguished from all other gases. It extinguishes flame, and is most deleterious when inhaled. As it is apt, from its great density to accumulate in the lower part of wells, pits, or mines, where it escapes, it is often the cause of fatal accidents. No such place should be entered until a light has been introduced, and found to burn brightly: if it burns dimly, or is extinguished, the air will certainly destroy life if respired.

Carbonic acid gas, by a pressure of 36 atmospheres, is liquefied. This is best accomplished by condensing the gas by means of a pump, into a strong copper vessel, such as is used for air-guns. The liquid carbonic acid, by its almost instantaneous evaporation, when allowed to escape through a jet, produces so much cold, as to freeze a part of the gas into a white solid like snow. The solid carbonic acid evaporates slowly, but, if mixed with ether, more rapidly, so as to freeze mercury easily. The liquid acid expands by heat in a greater degree than even the gas does.

Carbonic acid gas is absorbed by water, particularly under increased pressure, and gives to that liquid an acidulous taste, and the power of reddening litmus; although, on exposure to the air, or on boiling, the gas is given off, and the blue color is restored. With the bases, it unites, forming salts, which are called carbonates; but in the soluble carbonates the alkali is not neutralized, and many carbonates of the base, especially of ammonia, may be obtained, in all of which the properties of the alkali predominate. It would appear from this, that carbonic acid is not a true acid, although it combines with bases. We shall hereafter see that one or two other oxygen acids, which, like it, do not form hydrates, are, in like manner, destitute of the true character of acids.

The sparkling and effervescing properties of many kinds of wine, of beer, and of soda water, are owing to the presence of

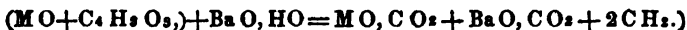
carbonic acid. The mineral waters, in which it occurs free, are known by their sparkling, and are much used.

CARBON AND HYDROGEN.

These two elements combine together in a vast number of proportions, and being both combustible, give rise to compounds, all of which are highly inflammable, and which resemble each other in chemical characters generally. They are often called carburetted hydrogens. At the ordinary temperature, some are solid, as paraffine and naphthaline; many are liquid, as oils of turpentine and lemons, naphtha, &c.; and two are gaseous, namely, light carburetted hydrogen gas, and olefiant gas. All of these compounds are either vegetable products, or arise from the decay or the destructive distillation of organic matter. As, however, the two gases, mixed in various proportions with air, constitute the fire-damp of coal mines, and consequently occur in the mineral kingdom, we shall describe them here, leaving the remainder for organic chemistry.

a. Light Carburetted Hydrogen. $\text{CH}_2 = 8.04$.

This gas forms the chief part of the combustible gases, which issuing from the seams in the coal, mixes with the air of the mines, and produces the explosive fire-damp. It is produced nearly pure, when vegetable matter decays under stagnant water. The bubbles which rise are found to consist of this gas, with a little carbonic acid, which may be removed by solution of potash. The gas may also be formed artificially by heating an acetate, MO , $\text{C}_2\text{H}_3\text{O}_2$, with an excess of hydrate of baryta. We have then



The gas is colorless and inflammable, burning with a yellowish flame, and forming carbonic acid and water with the oxygen of the air. $\text{CH}_2 + \text{O}_2 = \text{CO}_2 + 2\text{HO}$. Its Sp. G. is 0.5555. When mixed with twice its volume of oxygen and set fire to, it explodes violently. The same result follows, but with less violence, when it is mixed with 10 vols. of air, which contain 2 vols. oxygen. This is the nature of fire-damp. It is a mixture of this gas with air. If the air is less than 6 times, or more than 14 times the volume of the gas, explosion does not take place.

To put an end to the frightful accidents formerly so common in coal-mines, Davy invented his safety-lamp, which is only a common oil lamp, surrounded by wire gauze. Davy found that flame, which is incandescent gaseous matter, and intensely hot, could not pass through fine wire gauze, the gaseous matter being cooled by the contact with the metal, below the point at which it becomes luminous. Now, as it requires the heat of flame to fire the explosive mixture, it is evident that the flame of the lamp, not being

able to pass through the wire gauze as flame, but only as gaseous matter not incandescent, cannot fire the mixture which surrounds it. Since this beautiful contrivance was adopted, explosions have become much more rare in coal-mines; and there is good reason to believe that such as have occurred have arisen from neglect of the use of the safety-lamp, or from carelessness in using lamps, the gauze of which has been so injured by blows, or otherwise, as to allow the flame to pass.

When an explosion takes place, those who are not burnt or shattered, are generally suffocated by the carbonic acid, which is the product of the explosion.

b. Olefant Gas. $C_2 H_2 = 14.08$; or, $C_4 H_4 = 28.16$.

This gas occurs in the gaseous mixture of coal-mines, mixed with the preceding. It is prepared by heating 1 part of strong alcohol with 4 parts of oil of vitriol. The mixture blackens and gives off the gas, which may be collected over water. It is rendered quite pure by passing it through oil of vitriol, which removes some of the vapor of ether which is generally present.

Olefiant gas is transparent and colorless. When brought in contact with a flame in the air, it takes fire, and burns with a very luminous white flame. Mixed with its volume of chlorine, the two gases rapidly disappear, producing an ethereal or oily liquid, $C_4 H_4 Cl_2$: hence the name. But if mixed with 2 vols. of chlorine, and set fire to, the mixture burns off with a red flame, and an immense quantity of smoke, which is carbon deposited in the solid form, the hydrogen uniting with the chlorine. $C_2 H_2 + Cl_2 = 2 H Cl + C_2$.

When a light is applied to a mixture of 1 vol. of olefant gas, and 3 vols. of oxygen, or 15 vols. of air, a very violent explosion takes place, the products being carbonic acid and water. $C_2 H_2 + O_2 = 2 H O + 2 C O_2$.

CARBON AND NITROGEN.

Cyanogen. $C_2 N = Cy = 26.63$.

These elements in the nascent state, and in the presence of a base, combine to form a very remarkable compound, which, from being a chief ingredient in Prussian blue, has been called cyanogen. This compound is best obtained by heating a mixture of 6 parts of dried ferrocyanide of potassium, and 9 parts of bichloride of mercury in a flask, when cyanogen is given off in the form of a colorless gas, absorbed by water, having a very pungent and peculiar smell. Cyanogen gas is combustible, and burns with a beautiful purplish red flame. It is liquified by a pressure of 3 or 4 atmospheres.

Such are the leading external properties of this remarkable compound, which, in its chemical relations, however, acts most

frequently the part of a simple acid radical, entirely analogous to chlorine, bromine, iodine, or fluorine, forming an acid with hydrogen, and neutral salts with metals.

In fact, cyanogen is the type of the important class of compound acid radicals, which characterize the chemistry of organic bodies, although, as we have seen, they also occur in inorganic chemistry. But as cyanogen is exclusively a product of organized compounds, or of the destruction of organic bodies, the detailed description of its chemical relations, and of its numerous compounds, belongs to organic chemistry.

The composition of cyanogen is $C_2 N$; but as it plays the part of an elementary body, it is generally more convenient to employ for it the symbol Cy.

Carbon and nitrogen form another compound, $C_2 N_4$, which is also a compound radical, and is called mellone. Symbol, Me.

CARBON AND CHLORINE.

Carbon does not directly unite with chlorine; but when chlorine is made to act on certain organic compounds, which are decomposed by it, the carbon being presented to it in the nascent state, combines with the chlorine. There are several chlorides of carbon: 1. Dichloride of carbon, $C_2 Cl$; a white solid fusible and combustible body. 2. Protochloride of carbon, $C Cl$; a liquid, boiling at 160° . 3. Perchloride of carbon, $C_2 Cl_3$; a very fusible solid, boiling at 360° , combustible. None of these compounds have any practical interest.

Little, if anything, is known of the compounds of iodine, bromine, and fluorine, with carbon.

CARBON AND SULPHUR.

Bisulphide of Carbon. $CS_2 = 38.28$.

This compound is best formed by filling with fragments of recently ignited charcoal a wide cast-iron tube, which is placed in a somewhat inclined position across a furnace. The lower end of the tube is connected with Liebig's condensing apparatus, the wide glass tube of which is kept cold by iced water, and terminates in a two-necked bottle, also placed in ice-cold water; a tube in the second tubulature of the bottle, allows the escape of gaseous matter. The part of the iron tube containing the charcoal being now raised to a red-heat, a fragment of sulphur is introduced into the upper end, which is instantly closed. The sulphur melts, boils, and passes in vapor over the hot charcoal, which combines with it, forming bisulphide of carbon, which condenses in the bottle as a volatile liquid. A second fragment of sulphur is introduced very soon after the first; and if the proportion of sulphur introduced at once, and the heat of the charcoal be fortunately observed, a large quantity of the new compound may soon be obtained. The gases

disengaged appear to be a gaseous sulphide of carbon, chiefly formed when there is too little sulphur, and sulphuretted hydrogen, arising from the presence of hydrogen or water in the charcoal.

The bisulphide of carbon is purified by distillation in a very gentle heat, and then forms a very transparent, mobile, colorless liquid, of Sp. G. 1.272, sinking therefore in water, which has a peculiarly offensive smell of putrid cabbage. It is very volatile, boiling at 108° ; and very combustible, burning with a pale blue flame, and producing sulphurous and carbonic acids. It is insoluble in water, soluble in alcohol, ether, and oils. It dissolves sulphur and phosphorus readily; and these solutions, by spontaneous evaporation, yield fine crystals of those elements. It also dissolves camphor, essential oils, and resins.

Sulphide of carbon is occasionally used as an external application in burns; and it promises to be useful as a solvent for resins, many of which it dissolves readily, and thus forms varnishes, which, from its great volatility, dry very rapidly.

12. BORON. $B = 10.9$.

This element is found, in combination with oxygen, forming boracic acid in certain hot springs in the north of Italy; and as borate of soda (borax), on the shores of some lakes in Thibet.

From Boracic acid, boron is with difficulty obtained by the action of potassium, aided by heat, which removes the oxygen. Or it may be prepared by the action of potassium on borofluoride of potassium, when boron is separated: $KF, BF_3 + K_3 = 4KF + B$. The fluoride of potassium which is formed, is dissolved away by water, and the boron remains as a dark olive-colored powder. Boron is fixed in the fire, but if heated in oxygen gas, it burns brilliantly, being converted into boracic acid.

BORON AND OXYGEN.

Boracic Acid. $BO_3 = 34.939$

When boron is heated in air it burns like tinder, or as above stated, if heated in oxygen, with a brilliant light, and yields this acid. It is obtained by evaporating the hot springs of Sasso, in Italy, in a somewhat impure state, under the name of Sassoline, or crude boracic acid. It is best prepared by dissolving borax in four parts of hot water, and adding to the hot solution one-third of the weight of the borax of oil of vitriol. Borax is a borate of soda; the sulphuric acid takes the soda, forming a soluble salt, and the boracic acid is set free. Being very sparingly soluble in cold water, it is deposited on cooling, in scaly crystals, which are a crystalized hydrate of boracic acid: $BO_3 + 5H_2O$. These crystals are purified by being dissolved in the smallest possible quantity of boiling water after they have been washed with a little

cold water. On cooling, this solution deposits pure hydrated boracic acid.

When the crystals are heated to 212° , they lose half the water they contain; and this is probably water of crystallization. The residue is $2\text{B O}_3 + 3\text{H O}$; so that the original crystals may be represented as $2\text{B O}_3 + 3\text{H O} + 3\text{aq}$. When heated to redness, the acid melts, and, on cooling, forms a transparent brittle glass. It is quite fixed in the fire in close vessels, if dry; but it volatilizes readily with the vapor of water, so that a solution of boracic acid cannot be evaporated without notable loss. It is in this way, along with steam, that it is brought from great depths into the springs in which it is found.

Boracic acid is sparingly soluble in cold, readily in hot water. It is very soluble in alcohol, and its alcoholic solution burns with a flame mixed and tinged with pale green; a property characteristic of the compounds of boron.

It is a feeble acid, and reddens litmus slightly; it colors tumeric brown, like alkali. With bases it forms salts, called borates, which are for the most part insoluble. The alkaline borates alone are soluble. All the salts of this acid are very fusible, and promote the fusion of other bodies when mixed with them. Hence borax is much used as a blowpipe flux, which not only promotes fusibility, but at a red-heat dissolves silicious compounds to a clear, fusible glass.

No compounds are known of boron with hydrogen or nitrogen.

With chlorine boron combines when it is heated in the gas, or when chlorine is passed over a red-hot mixture of boracic acid and charcoal. The tetrachloride of boron, B Cl_4 , is a gas at ordinary temperatures. It has a pungent acid smell, and forms thick vapors in the air. These are the results of its action on the water of the atmosphere, whereby hydrochloric and boracic acids are formed: $\text{B Cl}_4 + 3\text{H O} = 3\text{H Cl} + \text{B O}_3$.

Nothing is known of the compounds of boron with bromine and iodine.

BORON AND FLUORINE.

Terfluoride of Boron. $\text{B F}_3 = 66.94$.

Boron has a remarkable affinity for fluorine, and when fluor spar (fluoride of calcium) is heated to redness with boracic acid, a gaseous compound is produced, analogous in composition and properties to the tetrachloride of boron: $3\text{Ca F} + 4\text{B O}_3 = 3(\text{Ca O}, \text{B O}_3) + \text{B F}_3$. The Sp. G. of the gas is 2.36. It instantly seizes on water, decomposing it, and thus, like the chloride, forms very thick vapors with the moisture of the air. It is, in fact, a very delicate test of the presence of moisture in any gas.

When this gas is absorbed by water to saturation, hydrofluoric acid and boracic acid are formed: $\text{B F}_3 + 3\text{H O} = 3\text{H F} + \text{B O}_3$.

The hydrofluoric acid unites with the boracic acid and 1 eq. of water, forming an acid, $3\text{HF} + \text{H}_2\text{O}, \text{B O}_3$; and this, when acted on by bases, yields salts, the formula of which is $3\text{MF} + \text{M O}, \text{B O}_3$. Berzelius has shown that when terfluoride of boron is absorbed by concentrated hydrofluoric acid, another compound is formed, the formula of which is $\text{HF} + \text{B F}_3$. It is an acid, the formula of its salts being $\text{MF} + \text{B F}_3$. All its salts, when heated, give off terfluoride of boron.

Boron, when heated in the vapor of sulphur, burns and forms a sulphide of boron, which is a white solid decomposed by water, with which it yields sulphuretted hydrogen and boracic acid.

13. SILICON. $\text{Si} = 22.18$.

This element is, with the exception probably of oxygen, the most abundant of all those which form the solid mass of our earth. It occurs, however, only in a state of combination with oxygen, as silicic acid or silica, which is the chief ingredient of all rocks, except limestone, rock salt, and coal, and also of all soils.

Silicon is best obtained by heating potassium with silico-fluoride of potassium, $3\text{KF} + 2\text{SiF}_3$, which with 6 eqs. of potassium yields $9\text{KF} + \text{Si}$. Water dissolves off the fluoride of potassium, and leaves the silicon as a dark brown powder, which contains some hydrogen, and is purified by exposure to a low red-heat. Silicon is infusible, and after having been ignited in close vessels, it is so compact as not to burn when heated even in oxygen. It is not acted on by any acid except the hydrofluoric acid, which slowly dissolves it. A mixture of hydrofluoric and nitric acids acts more strongly. When silicon is fused with nitrate or carbonate of potash, it is oxidized with a smart deflagration. It is heavier than oil of vitriol.

SILICON AND OXYGEN.

Silicic Acid. $\text{Si O}_2 = 46.219$.

Syn. Silica.—This acid is found pure in rock crystal, or in white quartz. Along with small and variable quantities of certain metallic oxides it forms many well known minerals,—as yellow or smoke rock crystal with oxide of iron; agate, jasper, heliotrope, carnelian, with the same metal; amethyst with oxide of manganese; prase with oxide of nickel; rose-quartz with some fugitive coloring matter; opal and calcedony with water, &c., &c. Many sands and sandstones are nearly pure silica, and quartz rock and flint are quite pure.

Silicic acid may be obtained in a state of purity, from any silicious sand, by fusing it with three or four parts of carbonate of potash, dissolving the fused mass in water, adding hydrochloric acid, which separates the silica as a jelly, which is a hydrate of

the acid, and evaporating the whole to dryness. Water removes from the dry mass all soluble chlorides, and leaves the silica, which, when dried, is a snow-white powder, insoluble in water, and all acids except the hydrofluoric acid. It dissolves in caustic, or even carbonated alkalies, with the aid of heat.

Silicic acid combines with bases, forming silicates, all of which, except those containing an excess of the stronger alkalies, are insoluble in water. The greater number of rocks and minerals consist of silicates, especially those of alumina, lime, magnesia, oxide of iron, potash, and soda. The silicates of potash and soda, when heated to redness, form glass, which, when the acid predominates, is insoluble, and is the basis of all ordinary glass; when the alkali is in excess, the glass is very soluble in water. Many silicates found in nature, as the zeolites, are soluble in strong acids; but most of them lose their solubility on being ignited. Many, such as feldspar, are not attacked by acids, even before ignition.

No compounds are known of silicon with hydrogen or nitrogen.

SILICON WITH CHLORINE AND BROMINE.

When silicon is heated in chlorine it burns and forms a compound, which is better prepared by passing chlorine over a red-hot mixture of silicic acid and charcoal: $\text{Si O}_2 + \text{C} + \text{Cl}_2 = \text{Si Cl}_4 + 3 \text{CO}$. The compound, which is called tetrachloride of silicon, condenses in the cold part of the apparatus as a very volatile, pungent, and colorless liquid, which decomposes water, forming hydrochloric and silicic acids: $\text{Si Cl}_4 + 3 \text{H}_2\text{O} = 3 \text{HCl} + \text{Si}_2\text{O}_5$.

Bromine yields an analogous tribromide, Si Br_3 , the properties of which are similar to those of the tetrachloride.

Iodine is not known to combine with silicon.

Silicon and Fluorine. $\text{Si F}_4 = 78.22$.

Silicic acid is rapidly dissolved by hydrofluoric acid, and a gas is produced, which is found to be a tetrafluoride of silicon: $\text{Si O}_2 + 3 \text{HF} = 3 \text{H}_2\text{O} + \text{Si F}_4$. This gas is best obtained by heating a mixture of powdered fluor spar and quartz with oil of vitriol: $3 \text{Ca F}_2 + \text{Si O}_2 + 3 (\text{H}_2\text{O}, \text{SO}_3) = 3 (\text{Ca O}, \text{SO}_3) + 3 \text{H}_2\text{O} + \text{Si F}_4$. The gas must be collected over mercury. It is colorless, fuming strongly in the air; its Sp. G. 3.66. It is absorbed by water, and hydrated silicic acid is deposited, while an acid is found in the water, composed of $3 \text{HF} + 2 \text{Si F}_4$. With bases this acid forms salts, called silicofluorides, the formula of which is $3 \text{MF} + 2 \text{Si F}_4$. These salts are nearly all insoluble, and when heated give off tetrafluoride of silicon.

The aqueous hydrofluosilicic acid is used in chemistry to separate potash, with which it forms an insoluble salt, from certain

acids, such as chloric acid, by which means these acids are obtained in the free state. It is also used as a test, to distinguish between compounds of barium and of strontium, as it forms after a short time a crystalline deposit in the solutions of the former base only.

Heated with sulphur, silicon combines with it, forming a white earthy compound, SiS_2 . It decomposes water, yielding sulphuretted hydrogen and silicic acid: $\text{SiS}_2 + 3\text{H}_2\text{O} = 3\text{H}_2\text{S} + \text{SiO}_2$.

METALS.

GENERAL OBSERVATIONS ON METALS.

In the arrangement we have adopted, all the elements not hitherto described are considered metals, although some of them especially arsenic and tellurium, are, in many points, very analogous to the metalloids. The metals are forty-two in number, exclusive of the three lately announced by Mosander, the two announced by Rose, and one discovered by Klaus, which, if established, will raise the number to forty-eight. See the list of elements, page 26.

A metal is defined to be a body possessing the peculiar appearance called the metallic lustre, (which is well illustrated in polished silver or in mercury), and capable of conducting well both heat and electricity. All the metals possess this combination of characters, but in other physical characters they exhibit great variety. We shall notice the following: Specific Gravity, Hardness, Tenacity, Fusibility, and Volatility.

1. Specific Gravity. The density of metals varies from 0.86: (water being = 1) to 21: the former being the Sp. G. of potassium, the latter that of platinum. Iridium is said to be still denser than platinum.

2. Hardness. Some metals, as potassium, lead, tin, silver, &c., are so soft as to be easily cut with a knife; potassium and sodium may even be kneaded in the fingers. Others, such as iron, nickel, antimony, &c., are much harder; and a few, such as rhodium and iridium, especially the latter, possess a very high degree of hardness.

3. Tenacity. This property is present in very various degrees in metals. Some, as antimony, bismuth, cobalt, have so little tenacity that they are brittle and may be powdered: while others may be beat out into thin leaves, or drawn into fine wires. Those two forms of tenacity, malleability and ductility, are not always proportional to one another; for iron, which can only be beat into plates of a very moderate thinness, being, of all the malleable metals, the least malleable, may be drawn out into very fine wires, and is among the most ductile of metals. Of the malleable

metals, the following are remarkable : lead, tin, copper, palladium, platinum, silver, and gold. The last named metal may be beat out into leaf so fine, that, although quite entire and free from visible pores, 57 square inches of the finest gold-leaf will not weigh more than 1 grain. Zinc, which is rather brittle at ordinary temperatures, admits of being rolled into thin plates at 300° and 400°. The most ductile metals are lead, copper, palladium, iron, silver, gold, and platinum. 1 grain of gold may be drawn out into a wire 550 feet long, and platinum is about 6 times more ductile, according to Wollaston. Iron wire, although not the finest, is stronger than wire of equal diameter of any other metal.

4. Fusibility. One metal, mercury, is liquid at all temperatures above — 39° F., and below 660°. Some, such as potassium, sodium, &c., melt at a very moderate heat : others, such as lead, tin, &c., at temperatures below red-heat ; others at a strong red or white-heat, such as copper, silver, and gold. Some, as platinum, rhodium, &c., require the heat of the oxygen and hydrogen blowpipe to melt them ; and one, at least, iridium, appears to resist, when pure, even this intense heat.

5. Volatility. Some metals are very volatile compared with others. Mercury volatilizes very slowly at all temperatures above 80° or 100° F., and below its boiling point, at which temperature, 662°, it is rapidly converted into vapor. At the other extreme is iridium, which is quite fixed, not even melting in the strongest white-heat yet known. The following metals are converted into vapor, or they boil, at temperatures varying from a low to a bright red-heat : cadmium, zinc, arsenic, tellurium, potassium, and sodium. Most of the others are fixed, although some of them, in the flame of the oxy-hydrogen blowpipe, appear to be volatilized in small quantity.

The chemical relations of metals are very important ; and as there runs through the whole class a great analogy in this respect, it is advisable to describe, generally, the chemical characters of metals ; by which means we are enabled to render the account of the individual metals more brief, and more easily remembered.

Metals have powerful affinities, especially for the metalloids, with almost all of which they combine, and frequently in several proportions. In addition, therefore, to the important uses of the metals, as such, the useful applications of a large number of metallic compounds are of the highest interest and value.

Almost all the metals have a powerful affinity for oxygen, and all of them may be made to combine with it. In like manner the metals have strong affinities for, and may easily be made to combine with chlorine, bromine, iodine, fluorine, (to which may be added cyanogen), as well as sulphur, selenium, and in many cases, phosphorous and carbon ; in a few, hydrogen and silicon. Metals also combine with each other. Owing to the extensive

range of these affinities, metals are rarely found uncombined, or native, as it is called, and the operations of metallurgy are chiefly such as are required to separate metals from the compounds in which they occur, which are called their *ores*. Oxygen in the atmosphere and in water, being far more abundant than the other metalloids, metals are chiefly found oxidized, and are therefore commonly extracted from the ores by processes of deoxidation, or reduction, as it is termed.

METALS WITH OXYGEN.

Metals differ in the degree of their attraction for oxygen. Some metals, such as potassium, rapidly combine with oxygen when exposed to the air, or when brought in contact with water or with any other oxidized compound. Others, such as iron, are very slowly oxidized by exposure to the air at ordinary temperatures, and hardly act on cold water; but at a strong red-heat they burn in the air, and decompose the vapor of water, setting free hydrogen gas. Others again combine with oxygen when heated in air, but do not decompose water at all, such as copper. These, as well as the preceding, are in general easily oxidized by acids; and their attraction for oxygen is such, that their oxides once formed, are not decomposed by a red-heat alone, without the help of combustible matter. Finally, some metals, such as gold and silver, &c., have much less attraction for oxygen. They are not so easily or directly oxidized, and the oxides, once formed, are quite easily decomposed by a red-heat, being resolved into metal and oxygen.

When metals combine with oxygen, they form three classes of oxides.

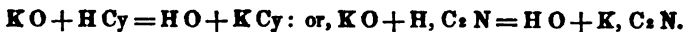
1st. Bases, or basic oxides, the most usual formula of which is MO ; such oxides are called protoxides. Besides protoxides, a pretty numerous class of basic oxides has the formula M_2O_3 : these are sesquioxides. A very few basic oxides have the formula MO_2 : these are binoxides or deutoxides. Potash, KO , is an example of a protoxide; sesquioxide of iron, Fe_2O_3 , of a sesquioxide; and deutoxide of tin, SnO_2 , of a basic deutoxide.

All basic oxides form neutral salts by combining with acids. In all such cases there is produced, besides the neutral salt, a quantity of water, the oxygen of which, according to the most probable view, is derived from the metallic oxide. Its hydrogen must therefore be derived from the acid, and in the case of the hydrogen acids with simple radical: this is admitted by all. For example, when potash, KO , acts on hydrochloric acid, HCl , the change is universally admitted to be as follows:

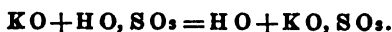


That is, the basic oxide, and the hydrogen acid, give rise to water and to chloride of potassium, both neutral substances. Neither

have we any difficulty in adopting the same view in the case of a hydrogen acid with a compound radical ; for example, hydrocyanic acid :



But when we bring potash in contact with oil of vitriol or strong sulphuric acids, most chemists are inclined to adopt a different explanation of phenomena precisely analogous. They call the acid hydrated sulphuric acid, H O, SO_3 , and express the action as follows :

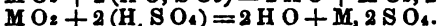
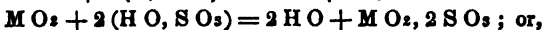
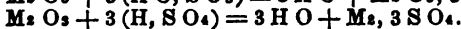
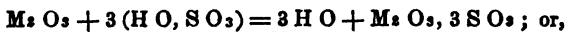


Here, it will be observed, the results are quite similar to those in the preceding cases ; namely, the separation of water, and of a neutral salt, in this case sulphate of potash. And yet we adopt a different explanation, at least on the older view of acids and salts, supposing the water to pre-exist in the acid, and to be replaced by the oxide. As it is, however, quite unphilosophical to employ two explanations of analogous facts if one will suffice, we are thus induced to prefer the newer view of acids and salts formerly alluded to, which admits of our giving the same explanation of the two cases. According to this view, then, we consider oil of vitriol a hydrogen acid, H, SO_4 , and express the change thus :

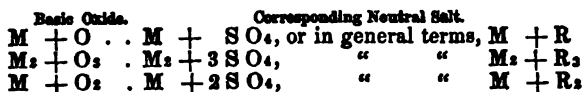


On comparing this with the equation above given for the action of potash on hydrocyanic acid in its second form, it will be seen that the analogy is perfect. Both acids and both salts contain a compound acid radical, in the one case C_2N , in the other SO_4 ; and both differ from the acid and salt of chlorine, in the fact of their radicals being compound, or rather *known to be* compound : for chlorine may very possibly be itself a compound radical, although at present we must view it as simple, because it is undecomposed.

The action of a basic sesquioxide, and of a basic deutoxide, on an acid, say sulphuric, is represented as follows, on both the different theories of acids :

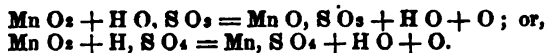


Here we see that, for every equivalent of oxygen in the base, an equivalent of acid is required to form a neutral salt ; and that, on the new view, the resulting neutral salts are compounds corresponding to the basic oxides from which they are formed. Thus we have,



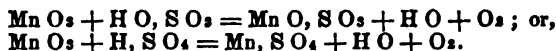
Such are the most important chemical relations of the basic oxides, which include, among the protoxides, the strongest alkalies and alkaline earths.

2nd. Neutral or indifferent metallic oxides. These appear, by combining with an additional quantity of oxygen, to have lost the basic, without acquiring the acid character. They commonly enter into few combinations of any kind. Their composition varies, being sometimes $M_2 O_4$, and sometimes $M O_2$. Red oxide of lead, $Pb_2 O_4$, is an example of the former; hyperoxide of manganese, $Mn O_2$, of the latter. When heated with acids, oxygen is given off, while a basic oxide is formed, and acts on the acid as above, forming a neutral salt. Thus, peroxide of manganese, heated with oil of vitriol, gives,



3rd. Metallic acids. These are pretty numerous. When the same metal forms a basic oxide and an acid, the latter always contains more oxygen. There are several different formula among metallic acids. They are sometimes sesquioxides, as $As_2 O_3$, arsenious acid; sometimes deutoxides, as titanous acid, $Ti O_2$; very often teroxides, as chromic acid, $Cr O_3$; occasionally $\frac{2}{3}$ oxides, as arsenic acid, $As_2 O_5$; and in one case a quadroxide, as osmic acid, $Os O_4$.

Metallic acids, when heated, generally lose oxygen, and are reduced to the basic oxide; this takes place especially if they are heated with acids. Thus, manganic acid, $Mn O_3$, heated with sulphuric acid, yields oxygen gas and neutral sulphate of the protoxide:



When we wish to form metallic acids, we commonly heat or deflagrate the metal, or its lower oxides, along with an alkaline nitrate or chlorate, in which case the acid that is formed remains in combination with the alkali. Or chlorine gas is passed through water in which the oxide, in fine powder, is suspended; sometimes along with an alkali, sometimes alone.

When our object is to deprive metals of the oxygen with which they are combined, or to reduce them, as it is called, to the metallic state, different methods are followed, according to the attraction of the metal for the oxygen.

1. The oxides of the noble metals, such as mercury, silver, gold, platinum, &c., are reduced by a red-heat alone.

2. The oxides of a large number of metals, such as copper, iron, tin, barium, or potassium, can only be reduced by the united action of heat and combustible matter, such as carbon, hydrogen, &c. The change is as follows: $MO + C = M + CO$; or, $MO + H = M + H_2O$. In the former case carbonic oxide gas, in the latter water, is produced, and being expelled by the heat, leaves the metal pure. The use of carbon for reduction is the foundation of all the metallurgic processes on the large scale. As the ores, however, are not pure, substances called fluxes are added to cause the impurities to melt, forming a fluid glass, below which the melted metal is found.

Perhaps the most powerful reducing or deoxidizing compounds at a red-heat are the formiates, and cyanide of potassium. The formula of a formiate is $MO, C_2H_3O_2 = MO + H_2O, 2CO$: so that it yields at a red-heat carbonic oxide gas, a body having much attraction for oxygen. Cyanide of potassium is $KCy = K, C_2N$; and, as Liebig has pointed out, it combines the very powerful deoxidizing agency of carbon and of potassium. Its reducing power is very great.

3. The oxides of the metals of some of the alcalies and earths, whose attraction for oxygen is very strong, and which are with difficulty reduced in any other way, are decomposed by a powerful galvanic battery so as to yield the metals. This is only done on a very small scale.

4. Many oxides in solution are reduced to the metallic state by other metals having a stronger attraction for oxygen, which take the place of the metal previously in solution. Thus copper precipitates silver, and iron precipitates copper.

5. Many oxides in solution, that is, combined with acids, are reduced to the metallic state by what are called deoxidizing agents. Thus the noble metals, such as gold, platinum, &c., are reduced by sulphurous, phosphorous, and hypophosphorous acids and their salts; by oxalic and formic acids and their salts: gold is even reduced by hydrogen gas and by solutions of protosalts of iron, such as green vitriol. In all these cases the reducing or deoxidizing agent is oxidized; phosphorus acid, for example, yielding phosphoric, and protoxide of iron passing into peroxide, at the expense of the metallic oxide.

The electrotype, in which copper, silver, gold, or platinum, are reduced to the metallic state in such a way as to form coherent masses similar to the hammered metals, and by which the most beautiful and perfect copies of medals may be taken, is a process depending partly on the reducing agency of the galvanic battery, partly on that of hydrogen gas, which, instead of escaping uncombined at the negative pole, is then oxidized at the expense of the metallic oxide. In this process, which is minutely described in works devoted to the subject, it is essential that the electric current

should be slow and uniform, otherwise the metal is deposited in different states. Plating and gilding by this process have a beautiful appearance, and are perfectly adapted for objects not subjected to much wear or friction.

METALS WITH HYDROGEN.

Only a few metals unite with hydrogen, and these form gaseous and combustible compounds not yet known in a pure state, but only in a state of mixture with hydrogen gas. The following metals only are as yet known to combine with hydrogen: zinc, potassium, arsenic, antimony, and tellurium.

METALS WITH NITROGEN.

Until lately metals were not known to combine with this element: but we are now acquainted with compounds of nitrogen with copper, chromium, and mercury. These compounds are black or dark brown powders, which may be obtained by passing dry ammoniacal gas over the oxides of the metals, gently heated, water being at the same time produced and nitrogen gas liberated. Thus, when oxide of copper is acted on by ammonia, we have $6 \text{CuO} + 2 \text{NH}_3 = 6 \text{H}_2\text{O} + \text{N}_2 + 3 \text{Cu}$. Like the compounds of nitrogen with chlorine and iodine, these compounds are easily made to explode, their elements separating with violence, and with a flash of light, by a gentle heat or friction, or percussion. It is possible, or indeed probable, that fulminating gold and silver, prepared by the action of ammonia on the oxides of these metals, and the explosive tendencies of which render them so very dangerous, are in reality the compounds of metals with nitrogen. These must be distinguished from the other fulminating silver, which, like fulminating mercury, is a compound of oxide of the metal with fulminic acid.

METALS AND CHLORINE.

The attraction or affinity between chlorine and metals is very strong. Many metals, such as potassium, copper, gold, antimony, &c., combine instantaneously with chlorine without the aid of heat, but with the phenomena of combustion. Others, such as mercury, &c., burn in chlorine only when they are heated in the gas. By combining with chlorine, metals give rise to chlorides, which may be often more advantageously formed by other means than by direct combination with the gas. Other methods of obtaining chlorides are the following:

1. Chlorine gas is passed over the oxide or sulphide of the metal heated to redness. In many cases the affinity of chlorine prevails, and the oxygen or sulphur is expelled: $\text{MO} + \text{Cl} = \text{MCl} + \text{O}$.
2. Hydrochloric acid gas is passed over the oxide or the sulphide heated to low redness. Here the affinity of hydrogen for oxygen or sulphur, added to that of chlorine for the metal, effects decom-

position, which chlorine alone could not accomplish: $\text{M O} + \text{H Cl} = \text{M Cl} + \text{H O}$: $\text{M S} + \text{H Cl} = \text{M Cl} + \text{H S}$.

3. To the solution of an oxide, in water or in acids, hydrochloric acid or a soluble chloride is added. If the metal forms an insoluble chloride, that is at once precipitated, showing that the change must be, as in the case of the dry gas, $\text{M O} + \text{H Cl} = \text{M Cl} + \text{H O}$. If the metal, as in the case of potassium, forms a soluble chloride, then the addition of hydrochloric acid causes no visible change; but on evaporation, crystals are deposited, which are generally found to be of a chloride, and free from oxygen or hydrogen. Thus, potash, K O , with hydrochloric acid, H Cl , undergoes, in solution, no change of appearance at first; but on evaporation yields cubical crystals, which are found to be K Cl .

4. Some metals, as gold and platinum, are converted into chlorides by dissolving them in aqua regia, or nitro-muriatic acid, and evaporating gently to dryness with an excess of hydrochloric acid. The dry residue is pure chloride.

When metals are combined with chlorine they may be reduced to the metallic state by various means.

1. Some chlorides are reduced by heat alone, which expels the chlorine. This is the case with almost all the chlorides of the noble metals.

2. Other chlorides are reduced by the action of another metal. Thus, chloride of platinum or chloride of silver is reduced by means of zinc.

3. Many chlorides are reduced by hydrogen gas at a red-heat, but not by charcoal, as oxides are.

4. The chlorides of the noble metals are reduced by boiling their solutions with a formiate; those of gold and platinum also by the protosulphate of iron. Chlorides may also be reduced by fusion with formiates or with cyanide of potassium.

What has been said of the relation of metals to chlorine applies almost exactly to their relations with bromine, iodine, fluorine, and cyanogen, which in its combination with metals plays the part of a salt radical, entirely analogous to chlorine.

The chlorides, bromides, iodides, and cyanides of metals are true salts, for the most part neutral salts. Indeed, sea-salt, the type of all salts, is chloride of sodium, Na Cl . None of these compounds possess decided acid or basic characters; but the chlorides, &c., are capable of combining together and forming double chlorides, &c., which have been compared by Bonsdorff to oxygen salts. Thus viewing, as he did, chromate of potash, K O , C O_2 , as an oxygen salt, he viewed the following compound, K Cl , Hg Cl_2 , as a chlorine salt. The former contains, according to him, an oxygen acid, Cr O_3 , and an oxygen base, K O ; the latter, a chlorine acid (bichloride of mercury), Hg Cl_2 , and a chlorine

base, KCl , (chloride of potassium). But it is to be observed that neither KCl nor $HgCl_2$ have basic or acid properties; they are, on the contrary, neutral salts, and, according to the more probable views now beginning to prevail as to the true nature of salts, which are considered compounds of metals with salt radicals, the compound $KCl + HgCl_2$ is viewed as a double salt. The same view applies to a large number of analogous double chlorides, bromides, iodides, fluorides, and cyanides.

METALS WITH SULPHUR.

All the metals are capable of combining with sulphur, and many metallic sulphides are found native: those of iron, copper, lead, antimony, zinc, and bismuth in abundance: those of mercury, silver, cadmium, and some others, more sparingly.

Most metals when heated along with sulphur combine with it; but in many cases sulphides are obtained by the action of sulphur compounds on the oxides, or by the deoxidation of sulphates.

1. When an oxide is exposed to the action of sulphuretted hydrogen gas, aided by heat, water and a sulphide are formed, $MO + HS = HO + MS$. The same change takes place when a solution of sulphuretted hydrogen or a current of the gas is made to act on solutions of oxides in acids. The sulphides of the following metals may be thus obtained, being all insoluble in water:

GROUP I. Metals, the oxides of which, in acid solutions, are precipitated as sulphides by sulphuretted hydrogen.

Metals.	Color of Precipitate.	Metals.	Color of Precipitate.
Cadmium	Orange.	Platinum	Black.
Lead	Black.	Iridium	Black.
Bismuth	Black.	Gold	Black.
Copper	Black.	Tin, protoxide	Brown.
Silver	Black.	Tin, peroxide	Yellow.
Mercury	Black.	Antimony	Reddish-orange.
Palladium	Black.	Molybdenum	Brown or Red.
Rhodium	Black.	Tungsten	Brown.
Osmium	Black.	Vanadium	Dark brown.
Tellurium	Yellow.	Arsenic	Orange-yellow.

The other metals are not precipitated by sulphuretted hydrogen, but the following yield sulphides when their oxides in solution are acted on by hydrosulphide of ammonia (sulphide of ammonium), or by a soluble metallic sulphide:

GROUP II. Metals, the oxides of which are precipitated as sulphides by soluble sulphides, although not by sulphuretted hydrogen.

Metals.	Color of Precipitate.	Metals.	Color of Precipitate.
Manganese	Flesh color.	Cobalt	Black.
Iron	Black.	Nickel	Black.*
Zinc	White.		

* Alumina is precipitated white by soluble sulphides, but the precipitate is not sulphide of the metal, but only hydrated oxide.

The remaining metals, those of the alkalies and earths, form a third group, the sulphides of which being soluble do not appear as precipitate.

2. When a sulphate of a metallic oxide, M O , S O_2 , or M, S O_4 , is acted on by hydrogen or carbon at a strong red-heat, it is entirely deoxidized, and the sulphide of the metal is left. Thus, if sulphate of baryta, K O , S O_2 , or K, S O_4 , be mixed with about one-sixth of its weight of charcoal, and exposed for two hours to a bright red-heat in a vessel closed, except where a small aperture is left for the escape of gaseous matter, carbonic oxide is given off and sulphide of barium is left: $\text{Ba O, S O}_2 + \text{C} = 4 \text{ CO} + \text{Ba S}$.

The sulphides of each metal are commonly equal in number and analogous in composition to its oxides. Metallic sulphides unite together, as oxides do, and produce double sulphides or sulphur salts, which are closely analogous to oxygen salts.

Thus we have,

Oxygen Salts.		Sulphur Salts.	
Oxygen Acids.	Oxygen Base.	Sulphur Acids.	Sulphur Base.
With Molybdenum	$\text{Mo O}_2 + \text{K O}$	$\text{Mo S}_2 + \text{K S}$	
With Arsenic . .	$\text{As O}_2 + \text{K O}$	$\text{As S}_2 + \text{K S}$	
.....	$\text{As O}_2 + 3 \text{ K O}$	$\text{As S}_2 + 3 \text{ K S}$	

Of course, if we view the oxygen salt, $\text{As O}_2, 3 \text{ K O}$, for example, as a compound of a metal with a salt-radical, $\text{As O}_2, \text{K}_3$, the corresponding sulphur salt, $\text{As S}_2, 3 \text{ K S}$, becomes $\text{As S}_2, \text{K}_3$. The analogy between the compounds of sulphur with metals, and those of oxygen with the same bodies, has been shown by Berzelius to be very complete.

With selenium and tellurium metals form compounds very analogous to the sulphides.

With phosphorus some metals combine and yield compounds called phosphides, few of which are known. The alkaline phosphides, as those of barium and calcium, yield by the action of water phosphuretted hydrogen gas, which takes fire spontaneously.

Metals combine in several cases with carbon, forming compounds which are called carbides. They are generally brittle solids, and the only useful carbides are those of iron, which are two valuable compounds, steel and cast iron.

As all the compounds of metals with chlorine, bromine, iodine, fluorine, sulphur, and selenium, contain along with the metal a radical which forms an acid by combining with hydrogen, while the metal generally forms a base with oxygen, the question arises what takes place when such metallic compounds are dissolved in water? Does the metal seize the oxygen, and the radical the hydrogen of an equivalent of water, and do the acid and base thus produced combine together?

In the case of an insoluble chloride, such as that of silver, we know that the hydrochloric acid does not combine with the

oxide when both are mixed in solution, for the precipitate is found to be Ag Cl. Here the oxygen of the base and the hydrogen of the acid must have formed water: $\text{Ag O} + \text{H Cl} = \text{H O} + \text{Ag Cl}$.

But when hydrochloric acid, H Cl, is mixed with potash, K O, or, what comes to the same thing, when chloride of potassium, K Cl, is dissolved in water, what is the compound present in the liquid? Is it K Cl simply dissolved as such? or, is it a salt, K O + H Cl? We know that the liquid, if evaporated, yields crystals of K Cl, but it is possible that this compound may be formed by the force of cohesion when it crystallizes, and may not be previously present.

The general opinion of chemists is, that in most cases soluble chlorides, sulphides, &c., dissolve as such in water; but that in some cases the hydrogen acid does appear to combine with the oxide.

If K Cl, in dissolving, decomposes water, and forms K O + H Cl, then we must admit that in the act of crystallizing, when K Cl separates, water is again recomposed. These continual decompositions and recompositions of water, without any visible change of properties, are so improbable that in most cases we cannot admit their occurrence.

But there are cases in which the solution of a chloride, &c., is attended with a change of properties. Thus, chloride of magnesium and chloride of aluminum, when dissolved in water, cannot again be obtained in the anhydrous form. On evaporation oxide of magnesium or of aluminum are left, while hydrochloric acid escapes. Again, dry sesquichloride of chromium is peach-colored, but its solution is deep green, the color of all solutions containing sesquioxide of chromium; dry chloride of cobalt is blue, and its solution is pink; like all solutions containing oxide of cobalt.

In these and a few more similar cases, we can hardly doubt that water is decomposed when a chloride, &c., is dissolved; but in the great majority of cases we have no evidence of this; and therefore, it may be laid down as a general rule that chlorides and analogous compounds dissolve as such in water, and that hydrogen acids mutually decompose metallic oxides, yielding water and compounds of the metal with the radical of the hydrogen acid. To this rule there are some exceptions; some chlorides, &c., in dissolving, decompose water, producing a hydrogen acid and an oxide; and hydrogen acids are capable of combining with some oxides without mutual decomposition, the compounds, however, not being very stable.

METALS WITH METALS.

Metals are capable of combining together, and forming compounds which retain the metallic character, and many of which

are highly useful. They are called alloys, except where mercury is one of the metals, when they receive the name of amalgams. Thus, brass is an alloy of copper and zinc; pewter an alloy of lead and tin; German silver an alloy of copper, zinc, and nickel. The metal used for silvering the backs of mirrors is an amalgam of tin and lead; that is, it contains mercury with these metals. The alloys will be briefly described hereafter.

The progress of modern chemistry has added largely to the number of the elementary metals. Before the middle of last century the metals known were only such as had long been used in the arts or in medicine, and did not exceed twelve in number. From that period many new metals were gradually discovered in the mineral kingdom; and, in 1807, Davy's discovery of the metals of the alkalies at once added a numerous class of metals to the list. Wollaston and Smithson Tennant had previously, in 1803, discovered the four remarkable metals associated with platinum in its ores. The whole number of ascertained metals is now forty-two; and within the last year or two, Mosander has announced the discovery of three new metals, accompanying cerium and yttrium, Rose that of two, associated with columbium, and Klaus that of one more in the ore of platinum. These, if established, will raise the number to forty-eight.

In considering the metals individually, we shall arrange them in groups or classes, according to their affinities for oxygen and to their chemical relations.

CLASS I. includes twelve metals, subdivided into three well-marked orders.

Order 1. Metals of the alkalies proper, namely,

Potassium. Sodium. Lithium.

These metals have so strong an affinity for oxygen that they are rapidly oxidized by exposure to the air, and decompose water with violence, disengaging hydrogen gas, which generally takes fire. Their oxides are powerful bases or alkalies, very soluble in water and very caustic.

Order 2. Metals of the alkaline earths, namely,

Barium. Strontium. Calcium. Magnesium.

These metals have also a very strong affinity for oxygen, and, except magnesium, they decompose water at ordinary temperatures, but without flame. Their oxides are powerful bases, but less soluble and caustic than the alkalies; indeed, oxide of magnesium is insoluble. As they are thus intermediate between the alkalies and the earths proper, they are called alkaline earths.

Order 3. Metals of the earths proper, namely,

Aluminum. Glucinum. Yttrium.
Thorium. Zirconium.

These metals do not decompose water at ordinary temperatures, but burn in air when heated, forming oxides, which are less powerful bases than the preceding; and being quite insoluble in water and earthy in aspect, they are called the earths.

CLASS II. includes thirty metals; which are also subdivided into three orders. All these metals combine with oxygen, and in general their protoxides are insoluble and of an earthy aspect, but colored, and have basic characters, in many cases very powerful. A considerable number of these metals form acids with a larger proportion of oxygen. This class contains all the heavy metals, and all those which, from their malleability, ductility, &c., have long been used by mankind.

Order 1. Metals, the protoxides of which are powerful bases, but which do not decompose water unless with the aid of a red-heat: namely,

Manganese.	Tin.	Cobalt.
Zinc.	Cadmium.	Nickel.
Iron.		

Order 2. Metals which do not decompose water at any temperature; but the oxides of which, once formed, cannot be reduced by heat alone: namely,

Arsenic.	Columbium.	Bismuth.
Chromium.	Antimony.	Titanium.
Vanadium.	Uranium.	Tellurium.
Molybdenum.	Cerium?	Copper.
Tungsten.	Lanthanium?	Lead.

It is doubtful whether cerium and lantanium do not belong to the preceding order, to which also belong, in all probability, the three new metals of Mosander—Didymium, Erbium, and Terbium.

Order 3. Metals, the affinity of which for oxygen is so feeble that their oxides are reduced by a red-heat: namely,

Mercury.	Platinum.	Osmium.
Silver.	Palladium.	Iridium.
Gold.	Rhodium.	Ruthenium?

Owing to the comparatively feeble affinity for oxygen of these metals, they have no tendency to rust when exposed to the air, as iron does, for example, from its strong attraction for oxygen. Hence they retain the brilliant lustre of their polished surface, and do not wear by exposure to the air. They are therefore often called the noble or precious metals.

We now proceed to the description of the separate metals, which may be made very brief in consequence of our having so minutely described the general chemical characters of metallic bodies, the analogy among which is so great that the description of one is applicable, with but little change, to the others.

METALS.—CLASS I.

ORDER 1.—METALS OF THE ALKALIES PROPER.

14. POTASSIUM. $K = 39.15$.

SYM. *Kalium*.—This metal occurs chiefly in the ashes of land-plants as oxide of potash united to carbonic acid ; it is also found as chloride in the ashes of sea-plants. Many abundant rocks, such as felspar (with all its derivatives, such as clays), and mica, besides many simple minerals, contain potash in considerable quantity. It is contained also in most fertile soils, being necessary to the growth of plants, in the form of potash. Potassium was discovered in 1807, by Davy, who obtained it by the action of a powerful galvanic battery on hydrate of potash, KO , $H O$. At the negative pole oxygen was given off, and at the positive pole appeared hydrogen, derived from the water of the hydrate, along with the globules of a metal resembling mercury, which took fire in the air and burnt, reproducing potash. This expensive and troublesome method has long been abandoned, and potassium is now prepared by the action of charcoal at a white heat, on carbonate of potash, $K O$, $C O_2$.

A mixture of carbonate of potash with finely divided charcoal is first prepared by igniting cream of tartar in a covered crucible, which leaves such a mixture, well known as the black flux. This, while still warm, is mixed with a considerable proportion of charcoal in coarse powder and small fragments recently ignited, and allowed to cool in a covered crucible. The whole is now introduced into one of the hammered iron bottles used for holding mercury, coated outside with a mixture of sand and clay. The bottle is placed horizontally in a wind furnace, and a short wide tube of iron is fitted to it, to which tube is attached a copper receiver, partly filled with good naphtha, and having a diaphragm of copper, and on the further side of the receiver an aperture for the escape of gas, opposite the tube of the bottle : so that, if necessary, a strong steel rod may be introduced through this aperture and another in the upper part of the diaphragm into the tube, for the purpose of cleaning it out as it is apt to become choked. The receiver with the naphtha being surrounded with ice, a steady and uniform strong red or white-heat (by means of dry wood, the flame of which plays all round the bottle,) is applied to the bottle, and after a time potassium, which is known by the appearance of its pink flame at the mouth of the tube, distils over, accompanied with carbonic oxide gas, and with a gray powder, which is the cause of the occasional choking of the tube. The potassium drops into the naphtha, which protects it from the action of the air. To purify it entirely, it is re-distilled in a small iron retort along with a little naphtha into a receiver containing that liquid.

In this process the carbon deprives the oxide of potassium and the carbonic acid of their oxygen, forming carbonic oxide gas : $\text{K O}, \text{C O}_2 + \text{C} = \text{K} + 3 \text{C O}$. Were this all, we should have no other product but potassium and carbonic oxide. Unfortunately, however, carbonic oxide at a red-heat enters into combination with potassium, forming the gray powder above mentioned ; the composition of which is $7 \text{C O} + \text{K}_2 = \text{C}_7 \text{O}_7, \text{K}_2$. If, therefore, we consider the products obtained from 4 eqs. of carbonate of potash, they ought to be as follows, if the gray compound were not formed : $4 (\text{K O}, \text{C O}_2) + \text{C} = \text{K}_4 + 12 \text{C O}$. Instead of obtaining 4 eqs. of potassium, however, from 4 eqs. of carbonate, we only obtain 1 eq. as metal, the remaining 3 eqs. combining with carbonic oxide to form the gray powder : $\text{K}_4 + 12 \text{C O} = (\text{C}_7 \text{O}_7, \text{K}_2) + 5 \text{C O} + \text{K}$. This is the reason why the above process is not nearly so productive as might be expected. The gray powder must be kept under naphtha, as it is liable to be altered if exposed to the air, and especially to take fire and explode, if moistened with water. (This compound, by the slow action of the air, is converted into a very remarkable salt, rhodizonate of potash, to be hereafter mentioned, when carbonic oxide is treated of as a compound radical.)

Potassium is a metal of a bluish-white color, and a high degree of metallic lustre, so that a melted portion of it, under naphtha, resembles mercury or melted silver. At ordinary temperatures, it is so soft as to yield easily to the finger. At 150° it is quite fluid, and if cooled to 32° , it becomes brittle. At a low red-heat it boils, and may be distilled unchanged. Its Sp. G. is 0.865, so that it floats on the surface of water.

When exposed to the air it is instantly tarnished by the formation of a film of oxide ; and after a short time the whole is oxidized and converted into a white solid oxide, which soon attracts water from the atmosphere. Potassium must therefore be kept under naphtha, a liquid containing no oxygen. When heated in the air, potassium takes fire, and burns with a beautiful pink flame; oxide being formed. So powerful is its affinity for oxygen, that when thrown on the surface of water, it instantly decomposes it, with so much disengagement of heat as to set fire to the hydrogen gas which is separated : $\text{K} + \text{H O} = \text{K O} + \text{H}$. The hydrogen burning causes the potassium also to burn, combining with the oxygen of the air, and the globule swims about until it is consumed, burning on the surface of the water with a beautiful pink flame. The same phenomenon appears if the metal be placed in a small hollow on the surface of a piece of ice, when it instantly bursts into flame.

The affinity of potassium for oxygen and the other metalloids is so powerful that it has been the means of isolating many metals and some metalloids, whose attraction for oxygen, &c., is too

strong to be overcome by the usual means. Thus potassium decomposes the oxides or chlorides of aluminum, glucinum, yttrium, thorium, and zirconium, and the boracic and silicic acids. It is, consequently, a very powerful instrument of research.

The compounds of potassium to be here described are those which it forms with the metalloids.

POTASSIUM AND OXYGEN.

Potassium forms two compounds with oxygen, a protoxide, K O , and a peroxide, K O_2 .

a. Protoxide of Potassium. $\text{K O} = 47.163$.

This oxide is only formed when potassium is oxidized in dry air, or oxygen. It is a white powder, which rapidly absorbs moisture from the air, and deliquesces. It is now converted into the usual form, namely, hydrated oxide of potassium, or hydrate of potash.

SYN. Caustic Potash: K O , $\text{H O} = 56.176$. — This important compound is best prepared by acting on pure carbonate of potash, dissolved in water, so as to deprive it of carbonic acid. Two parts of carbonate are dissolved in twenty of boiling water in an iron pot, and one part of quick-lime, being previously slaked by covering it with boiling water, so as to form a kind of cream of slaked lime, is added to the boiling liquid in small portions, the mixture being allowed to boil a minute or two after each addition. When all the lime has been added, the whole is to be boiled for five minutes, care being taken to keep up the original quantity of water; since with less water the potash actually takes back the carbonic acid from the lime. The vessel, which ought to be more deep than wide, is then covered up with its lid, and allowed to stand for twenty-four hours. At the end of that time, if the above directions have been exactly followed, $\frac{1}{2}$ of the liquid may be decanted off perfectly clear and colorless. This is a pure solution of potash; and to obtain the hydrate, we have merely to boil it rapidly down, in a clean deep iron or silver vessel, till the residue flows like oil. It is then poured out on a plate of silver, and, on cooling, broken up into fragments, and preserved in well stopped bottles.

In the above process, the lime deprives the carbonate of potash of its carbonic acid, forming an insoluble carbonate of lime: H O , $\text{C O}_2 + \text{Ca O}$, $\text{H O} = \text{Ca O}$, $\text{C O}_2 + \text{K O}$, H O . By slaking the lime with hot water, it falls to so fine a powder that every particle acts, and we are thus enabled to use very little more than the atomic proportion of quick-lime, which would be about 28 to 69, instead of 1 to 2, or 28 to 56, as we employ. Again, by adding the lime gradually, and constantly boiling, the carbonate of lime assumes a very dense form, and settles perfectly to the bottom;

whereas if the lime were all added at once, it would yield a very bulky carbonate, from which the solution of potash would be with difficulty separated. By allowing the liquid to clear in the covered vessel, we avoid filtration, and consequently the bringing the potash in contact with the air, from which it absorbs carbonic acid, and is re-converted into carbonate. So effectual is the above process that the decanted liquid does not effervesce with acids, if carefully prepared; and if it be rapidly boiled to dryness, the solid hydrate may be also obtained free from carbonic acid.

The hydrate of potash is so valuable a re-agent to the chemist, that I have described minutely the best method of preparing it, which, as generally happens, is also the most simple. The solution, or aqua potassæ, is daily used in the ultimate analysis of organic bodies to absorb carbonic acid; and for this purpose, as well as for many others, it is obtained sufficiently pure from the pearlash, or impure carbonate of potash of commerce. The pearlash is to be treated precisely as the pure carbonate in the above process; and the decanted solution of caustic potash is to be boiled down until crystals begin to form in the boiling liquid, which is then allowed to cool in well stopped bottles of green glass. The crystals are sulphate of potash, a salt present in the pearlash, which is insoluble in a strong solution of caustic potash. On cooling, therefore, the whole of the sulphate crystallizes out, so that not a trace is left in the liquid. The clear liquid, decanted from the crystals, now contains no impurity, except chloride of potassium, which, for most purposes, is of no importance. It has a Sp. G. of 1.25 to 1.35, and is ready for use in organic analysis. If boiled to dryness, it yields a hydrate of potash, far purer than the hydrate of commerce, inasmuch as it is free from sulphate.

Hydrate of potash cast into small sticks, is much used by surgeons as a powerful caustic. The chief objection to its use is, that owing to its attraction for water, it deliquesces, and spreads farther than is intended. But in careful hands, it is easily managed, and is often used in preference to the knife, for opening glandular swellings, such as buboes, which have suppurated. When thus opened, and when the caustic has been applied to the inner surface of the cavity, they appear to heal better than when opened with the lancet. In chemistry, hydrate of potash is much used for the decomposition of minerals, by fusion with them, and for drying certain gases.

The solution of potash, aqua potassæ, or liquor potassæ, has the acrid corrosive taste of the hydrate; and when rubbed between the fingers, gives them a soapy feel, forming, in fact, soap with the oil of the skin. It turns infusion of red cabbage, of violets, dahlias, &c., green, and restores the blue of litmus reddened by acids. It is powerfully alkaline, or basic, neutralizing all acids. Its great attraction for carbonic acid has been already mentioned as the

reason for its being used in organic analysis, for the purpose of absorbing the carbonic acid derived from the carbon of the substance, and enabling us to ascertain its weight. For the same reason, potash in the form of solid hydrate, or in solution, must always be protected from the carbonic acid of the atmosphere. The solution, when of Sp. G. 1.060, is used in medicine as an antacid and lithontriptic. The chief use of potash is unquestionably that of promoting the growth of plants, to which it is generally essential, although it may frequently be replaced by soda or lime. Its function appears to be that of fixing the carbonic acid of the atmosphere, which with the elements of water, gives rise to the chief vegetable products, as will be explained in the second part. Hence all fertile soils contain it: hence also the value of the ashes of vegetables, as manure, depends in a great measure on the potash they contain; and the same remark applies to animal manures. Cow-dung, for example, is very rich in potash.

The presence of potash in any solution is best ascertained by the action of bichloride of platinum in solution, which, if any notable quantity of potash be present, forms with it a pale yellow precipitate of the double chloride of platinum and potassium. If the proportion of potash be very small, no precipitate may appear. In this case the liquid to be tested may be first concentrated by evaporation, and then again tested with the platinum salt, when the precipitate will in all probability appear; or alcohol may be added to the first mixture, in which the double chloride is quite insoluble. The only uncertainty in this test is, that ammonia gives a similar precipitate; so that we must first ascertain if ammonia be present, and if so, expel it by a red-heat, before testing for potassium.

Perchloric acid also causes, in solutions containing potash, a white precipitate of perchlorate of potash, sparingly soluble in water, and quite insoluble in alcohol; so that if but little potash be present, alcohol ought here also to be added.

An excess of tartaric acid produces, after a time, a crystalline deposit of cream of tartar, in solutions containing potash, more especially if well stirred with a glass rod, which causes the deposit to appear in streaks on the glass.

An alcoholic solution of carbazotic acid causes a yellow crystalline precipitate in solution of potash.

Lastly, hydrofluosilicic acid causes a gelatinous semi-transparent precipitate of silicofluoride of potassium, when added to solutions of potash. Of all these tests, the most certain is the bichloride of platinum, with the aid of alcohol.

b. Peroxide of Potassium. $KO_2 = 63.176$.

This oxide is formed by passing potassium over red-hot potash. It is an orange-yellow powder, which, when thrown into water,

is decomposed, oxygen being given off, and potash being found in the liquid.

POTASSIUM WITH HYDROGEN AND NITROGEN.

With hydrogen potassium forms two compounds, one of which appears to be a solid, the other gas. The latter seems to take fire spontaneously in contact with air, and is probably formed when potassium acts on water. The former is produced when potassium is heated in hydrogen gas. It is a gray solid decomposed by water.

When potassium is heated in dry ammonia, an olive-colored solid is formed, which is composed of potassium and amide (amidogen), $K, N H_2$. When this is heated, ammonia is given off, and there is left a substance resembling graphite, which is a compound of potassium and nitrogen: $3 (K, N H_2) = 2 N H_2 + N K_3$. This compound has been little examined.

POTASSIUM WITH CHLORINE, BROMINE, IODINE AND FLUORINE.

With all these elements potassium combines, with each in one proportion only, forming compounds which are very analogous to each other.

Chloride of Potassium. $K Cl = 74.57$.

This compound is a neutral salt, very similar to sea-salt. It is found in considerable quantity in the ashes of plants, especially of sea-plants. It is formed when potash is neutralized by hydrochloric acid, and the solution evaporated so as to form crystals: $K O + H Cl = H O + K Cl$. It is also left when chlorate or perchlorate is heated so as to expel all the oxygen: $K O, Cl O_2 = K Cl + O_2$.

It has a saline and bitterish taste, and is not much more soluble in hot than in cold water. It crystallizes, like sea-salt, in cubes. It is only used, when very cheap, in the manufacture of alum. It cannot be substituted for sea-salt, as a condiment, or antiseptic.

Iodide of Potassium. $K I = 165.45$.

This salt, which is very much used in medicine, resembles the preceding in external characters. It crystallizes in cubes, and is very soluble in water. To prepare it, iodine is dissolved in a pure solution of potash, with the aid of heat, until the liquid begins to assume a permanent brownish yellow color, indicating a slight excess of iodine. The liquid is now evaporated to dryness, and the dry residue ignited and melted in a covered platinum or iron vessel. The melted mass is poured out on a clean iron plate. It is iodide of potassium; and if dissolved in water and filtered if necessary, the solution on evaporation yields pure crystals of the salt. In the first stage of this process, iodate of potash and iodide of potassium are formed: $I_2 + 6 K O = 5 K I + (K O,$

IO_3). In the second stage, the iodate is converted by a red-heat into iodide of potassium, oxygen being given off, while the iodide already present is unaltered: $5\text{KI} + (\text{KO}, \text{IO}_3) = 6\text{KI} + \text{O}_2$.

Another method is to form iodide of iron by bringing iron and iodine in contact under water. The iodide of iron dissolves, and the filtered solution is decomposed by an equivalent weight of carbonate of potash in solution: $\text{FeI} + \text{KO}, \text{CO}_2 = \text{KI} + \text{FeO}, \text{CO}_2$. The insoluble carbonate of iron is separated by the filter, and the clear liquid evaporated till crystals are deposited.

Pure iodide of potassium is white, and dissolves entirely in hot alcohol. It is often adulterated with carbonate of potash, but that salt is easily detected by its insolubility in alcohol. The solution of iodide of potassium can dissolve a large quantity of free iodine, by which it acquires a deep brown color. This solution is much used for baths; and the iodide is employed both externally and internally in scrofulous diseases.

Bromide of Potassium. $\text{KBr} = 117.5$.

This salt is very analagous to the preceding, and is formed in the same way. It crystallizes in cubes, and is very soluble in water. It has not been applied to any use.

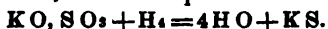
Fluoride of potassium, $\text{KF} = 57.8$, is obtained when hydrofluoric acid acts on potash: $\text{HF} + \text{KO} = \text{HO} + \text{KF}$. It is soluble and crystallizes in cubes, and is very analogous to the preceding salts.

POTASSIUM AND SULPHUR.

Potassium combines with sulphur in several proportions, of which the most important are, the protosulphide, KS , and the pentasulphide, or persulphide, KS_5 .

Protosulphide of Potassium. $\text{KS} = 55.2$.

This may be formed by melting together its constituents; but it is best prepared by passing hydrogen gas over neutral sulphate of potash, heated to bright redness. Here the hydrogen removes all the oxygen of the salt, and the sulphide is left.



Protosulphide of potassium is a solid of a bright red color, which forms with water a colorless solution. This solution smells of sulphuretted hydrogen, and probably contains that compound and potash, formed by the action of water on the sulphide: $\text{KS} + \text{HO} = \text{KO} + \text{HS}$. The solution is alkaline, and if pure is decomposed by acids, without any separation of sulphur, sulphuretted hydrogen being given off.

Pentasulphide or Persulphide of Potassium. $\text{KS}_5 = 119.5$.

This is the chief ingredient in what is called hepar sulphuris, or liver of sulphur, when prepared by fusing sulphur with car-

bonate of potash at the lowest possible temperature, when the persulphide is formed along with hyposulphite of potash: $3 \text{K O} + \text{S}_2 = 2 \text{K S}_2 + (\text{K O}, \text{S}_2 \text{O}_2)$. Alcohol dissolves the sulphide, which has a deep orange color. It may be obtained pure in solution by boiling the protosulphide with 4 eq. of sulphur and water. The persulphate of potassium forms an orange or yellow solution, which is decomposed by acids, with the deposition of a large quantity, 4 eq. of sulphur.

There are five other compounds of sulphur and potassium, all similar in properties to the persulphide. They are K S_2 , K S_3 , K S_4 , $\text{K}_2 \text{S}_7$, and $\text{K}_2 \text{S}_8$. The last two are probably $(\text{K S}_2 + \text{K S}_3)$, and $(\text{K S}_4 + \text{K S}_3)$.

POTASSIUM AND SELENIUM.

The relations between these elements appear to be closely analogous to those between potassium and sulphur: but the compounds formed are little known.

POTASSIUM AND PHOSPHORUS.

These elements, when heated together, combine to form a solid phosphide. When thrown into water, it gives rise to the disengagement of spontaneously inflammable phosphuretted hydrogen, while solid phosphuretted hydrogen separates, and hypophosphite of potash is found dissolved.

Nothing is known with certainty of the carbide of potassium, which is supposed by some to be formed in the process of making potassium.

No compound of potassium with silicon is accurately known: but with silicic acid potash forms compounds which are known as glass. When the silica predominates, we have ordinary hard insoluble glass: when the potash is in excess, the compound is called silicate of potash. It is a glassy mass, soluble in water, and the solution has long been known as liquor of flints. (See, hereafter, under the head of Salts, the silicates, including glass and porcelain).

15. SODIUM. $\text{Na} = 23.3$.

SYN. *Natrium*.— This metal, is, perhaps, more abundant in our globe than any other; for it constitutes two-fifths of all the sea-salt existing in sea-water, in the water of springs, rivers, and lakes, in almost all soils, and in the form of rock salt. Sea-salt is a compound of sodium with chlorine, Na Cl . Sodium also occurs as oxide of sodium, or soda, in a good many minerals; and more especially in the forms of carbonate, nitrate, and borate of soda: the first extracted from the soil in many parts of Africa; the second covering extensive plains in South America; and the third encrusting the shores of numerous lakes in Thibet. Soda is con-

tained in sea-plants, and in land-plants growing near the sea, in the latter apparently replacing potash; it is the chief base in kelp, varec, or barilla, which are the ashes of sea-weed. Soda also occurs in most animal fluids.

Sodium is obtained by a process exactly similar to that above described for potassium, substituting acetate of soda for cream of tartar. Owing to the fortunate circumstance that sodium does not combine with carbonic oxide, the process is much more productive than in the case of the former metal. In fact, when properly conducted, we may expect to obtain the whole of the sodium. Thus, in the laboratory at Giessen, 1 lb. of calcined acetate of soda (carbonate containing a little charcoal) mixed with $\frac{1}{4}$ lb. of finely-powdered, and $\frac{1}{4}$ lb. of coarsely-powdered charcoal, and heated in a malleable iron bottle, as above recommended, yielded nearly 5 oz. of sodium, even when it was obvious that the result was capable of considerable improvement; the whole of the sodium present being about 7 oz. From the extreme cheapness of carbonate of soda, and the productiveness of the operation, sodium can be prepared far cheaper than potassium, and may, in most cases, be substituted for that metal, as its affinities are almost equally powerful. Should this metal be ever required on the large scale, it might be obtained for a price little, if at all, higher than that of zinc.

Sodium is a silver-white metal, having a very high lustre. It has not the bluish tinge of potassium, but, if any, rather a very slight yellowish tint, so that it resembles silver, while potassium resembles mercury. Its Sp. G. is 0.9348; it melts at 200° , being rather less fusible than potassium: but it is, on the other hand, somewhat more volatile, which is one cause of its preparation being easier, since it distils over at a lower heat.

SODIUM AND OXYGEN.

The affinity of sodium for oxygen is next to that of potassium. It rapidly attracts oxygen from the air, and must therefore be kept under naphtha; but it is evidently less rapidly oxidized than potassium, and consequently keeps better. When heated in air or oxygen it takes fire, burning with a very pure and intense yellow flame, which is characteristic of sodium and of all its compounds. It decomposes water instantly, but does not spontaneously take fire when thrown on water, as potassium does. If the water, however, be thickened with gum, or if there be only a few drops of water, the action of sodium is attended with flame, and the yellow color of the flame is most conspicuous. When exposed to the air, or burned in air or on water, sodium forms the protoxide, or soda: but it can form two other oxides—the suboxide and the peroxide. The suboxide is little known; the peroxide is an orange powder, Na_2O_2 . The only important oxide is the

Protoxide of Sodium. $\text{Na O} = 31.313$.

Syn. Soda. — This oxide is formed when sodium is burned in dry air or oxygen. It is a white powder, which attracts moisture and carbonic acid from the air. When sodium is oxidized by water, or when the protoxide is dissolved in water, there is formed the true alkali, the hydrated oxide of sodium, or hydrate of soda, Na O, H O .

Syn. Caustic Soda. — This hydrate is prepared by a process exactly similar to that given for caustic potash, substituting carbonate of soda for carbonate of potash. If the carbonate of soda be in crystals, 1 part of quick-lime is sufficient for 5 or 6 parts of carbonate: if dry, 1 part of quick-lime will suffice, if pure, for 2 of carbonate. As the lime is seldom pure, it is in general safer to take 2 parts for 3 of dry carbonate of soda.

The solution of caustic soda, owing to the superior purity of the carbonate, which is generally free from sulphate and chloride, is much purer than the common aqua potassæ; and when boiled down, it leaves a very pure hydrate of soda: Na O, H O . This hydrate is, in all external characters, and in most chemical ones, exactly similar to caustic potash: it is deliquescent and caustic, and may be used for almost all the same purposes. The solution, however, cannot be used for organic analysis, as it froths up like solution of soap when a gas passes through it.

With acids soda forms salts, all of which, with hardly an exception, are soluble in water, and many of which crystallize. The solubility of its salts serves to distinguish soda from potash; for neither bichloride of platinum, tartaric acid, perchloric acid, nor carbazotic acid causes any precipitate in the salts of soda, even when alcohol is added. Hydrofluosilicic acid is the only test that forms a precipitate in cold and pretty strong solutions of soda salts; but the silicofluoride of sodium, thus formed, is much more soluble than the corresponding salt of potassium. When we know that either potash or soda is present, and the tests give the above negative results, we may safely decide on the presence of soda: but if we wish for positive evidence, this can only be obtained by setting fire to alcohol along with the suspected salt, or exposing the salt on platinum wire to the flame of the blowpipe; when, if soda be present, a rich and pure yellow color will be given to the flame.

The chief uses of soda are in the manufacture of glass and hard soap. The carbonate is used in washing, and is a powerful detergent, although milder than carbonate of potash.

SODIUM AND CHLORINE.

Chloride of Sodium. $\text{Na Cl} = 58.75$.

Syn. Muriate of Soda. Sea Salt. Rock Salt. Kitchen Salt. — This very important salt is formed when chlorine and sodium, or

hydrochloric acid and soda, come together. But it is found in immense quantity dissolved in sea-water, and in the water of salt springs, and in smaller quantity in all natural waters, by which, indeed, it is carried to the sea, where it accumulates. Inland seas, without any outlet, and where, consequently, the superfluous water escapes only by evaporation, become more saline than sea-water, although the streams which feed them are not richer in salt than ordinary rivers. Hence the Dead Sea in Palestine, fed by the Jordan, is a very strong brine, containing the same ingredients as sea-water, but far stronger; these ingredients being also the same which are found in the Jordan and all rivers, in much smaller quantity. Salt is also found abundantly, as rock salt, in various countries. It is obtained from the sea-water by simple evaporation, either spontaneous or with the aid of heat, till crystals separate, which are nearly pure chloride of sodium.

The properties of salt are well known. It is singular that it is not materially more soluble in hot than in cold water: for which reason it separates in crystals from the hot liquid during evaporation, and ought to be taken out from time to time with a perforated ladle, to allow the mother liquor to drain off.

One chief use of salt is as an antiseptic in curing meat. It seems to act chiefly by removing so much water from the flesh that too little is left to allow of putrefaction. Hence highly salted meat is always dry, and requires long steeping in water to render it eatable. Salt is also employed to yield hydrochloric (muriatic) acid, and chlorine, for the making of bleaching-powder, as well as the best carbonate of soda. In preparing hydrochloric acid from salt, which is done by the aid of oil of vitriol, sulphate of soda is formed; from which, by heating it with charcoal, carbonate of soda is obtained. Thus, in the very important manufacture of soda from salt, both the chlorine and the sodium are made use of; the hydrochloric acid being but a secondary product, formed in the first stage of the manufacture of carbonate of soda,—a product nearly equal in importance to the oil of vitriol, by means of which it is made.

But the most important use of salt, which renders it an absolute necessary of life to animals in some shape or other, is as a condiment to food, or rather as a substance indispensable to digestion. This subject will be fully treated of in the Second Part of this work. In the meanwhile it may be mentioned, that the free muriatic acid, always present in the chyme before it leaves the stomach, and the soda which is found in the chyle and in the blood, and which is the essential basic element of the bile, are both derived from salt, either originally present in the food, or, as is most commonly the case, added to it by man. Herbivorous animals, who produce an enormous quantity of bile, find salt in their food, and above all in the river or spring water they drink. But they

are so sensible of the good effects of salt, that they show the greatest preference for salt springs, and indeed for solid salt, if placed within their reach. When supplied with salt in moderate quantity they thrive uncommonly well, as in salt marshes, which are well known to give rise to very rich and well-feeding pastures. An excess of salt is, however, injurious.

SODIUM WITH BROMINE, IODINE, AND FLUORINE.

The compounds of sodium with these elements are quite analogous to those of potassium above described. The iodide and bromide of sodium are found in sea-water and in salt springs, in minute quantity. The formulæ of these three compounds are, Na Br , Na I , and Na F .

SODIUM WITH SULPHUR.

Sodium, like potassium, unites with sulphur in several proportions. The protosulphide, Na S , is very similar to the corresponding sulphide of potassium; the others are little known.

It is very remarkable that the beautiful mineral, lapis lazuli, or ultra-marine, the nature of the coloring matter in which was long a complete puzzle to chemists, should, according to recent discoveries, owe its magnificent blue color to the presence of sulphide of sodium, a compound destitute of any such color. But this seems to be really the case: for by heating a mixture of hydrated alumina and silicic acid to whiteness, along with sulphide of sodium, C. G. Gmelin has succeeded in preparing artificial ultra-marine, which is now prepared in France quite equal to the native pigment, and very much cheaper. We are still quite in the dark as to the true nature of the blue compound formed in this operation.

The compounds of sodium with phosphorus, carbon, boron, and silicon are unknown. With silicic acid, soda, like potash, forms glass.

16. LITHIUM. $\text{L} = 6.42$.

This metal is very rare, occurring only as oxide or lithia in a few rare minerals, such as spodumene, petalite, lepidolite, and lithion-mica. The metal has been obtained in small quantity by means of galvanism from the oxide, and is white, burning when heated, with a blood-red flame, and forming protoxide of lithium, or lithia.

Protoxide of Lithium. $\text{L O} = 14.43$.

This alkali can only be obtained from either of the above minerals, which are silicates. One part of the mineral in fine powder is mixed with two of fluor-spar, and the mixture heated with sulphuric acid, until the whole of the silica is dissipated. There then remains a mixture of sulphates of alumina, lime, and lithia, and in the case of lepidolite or spodumene, potash. By boiling with

carbonate of ammonia in excess, the alumina and lime are precipitated, and the filtered liquid is evaporated to dryness, and ignited to expel the sulphate of ammonia. The residue is sulphate of lithia, or sulphates of lithia and potash. In the latter case, by the cautious addition of chloride of barium, the sulphuric acid is separated as sulphate of baryta, and the lithia and potash converted into chlorides. These being dried, are digested in absolute alcohol, which dissolves the chloride of lithium. The lithia is now free from other bases: to obtain it in the separate state, the chloride is converted into sulphate, by being boiled with oil of vitriol, and the solution of the sulphate decomposed by the exact equivalent of barytic water, by which the sulphuric acid is precipitated, while the free lithia is dissolved, and the solution, if evaporated, leaves hydrate of lithia, L O, H O .

Lithia is not quite so soluble in water as soda or potash, nor is it so caustic; but it very much resembles these alkalies. Its solution attracts carbonic acid as readily as theirs from the atmosphere. When lithia is fused on platinum, it corrodes and stains the metal. Lithia and all its salts give a blood-red color to flame. The carbonate of lithia is sparingly soluble, and its phosphate is nearly insoluble. Lithia occurs too rarely to admit of any useful application; but it is important to know that lithion-mica, which is recognized by its easy fusibility before the blowpipe, and by its tinging the outer flame red, has hitherto been only found associated with albite and topaz, or pycnite, in tin districts, and its occurrence, thus associated, may be looked on as a sure indication of the existence of tin in the locality.

Chloride of lithium, L Cl , crystallizes in cubes. It is very deliquescent and soluble in alcohol, the flame of which it colors of a fine red.

APPENDIX TO THE FIRST, OR ALKALINE GROUP OF METALS.

Ammonium. $\text{N H}_4 = \text{Am} = 18.19$.

This hypothetical compound metal has already been described under the head of Ammonia, but we must here consider it as a metal, analogous to the three just described.

In all the salts of ammonia with oxygen acids Am O is found. This compound, oxide of ammonium $= \text{N H}_3, \text{H O}$, is itself a very powerful and caustic alkali, and neutralizes all the acids. It is important to observe that it is isomorphous with potash, K O ; so that the salt K O, S O_3 has the very same form as Am O, S O_3 .

Chloride of Ammonium. $\text{Am Cl} = \text{N H}_4 \text{ Cl} = \text{N H}_3, \text{H Cl} = 53.64$.

This is the well-known salt, sal ammoniac, which is analogous to K Cl , Na Cl , and L Cl , crystallizing, like them, in cubes. It is the salt from which ammonia and all its compounds are formed, and it is prepared from the impure carbonate of ammonia obtained

by distilling animal matters. It is entirely volatile, soluble in water, has a pungent saline taste, and no smell. Its chemical relations are those of a chloride, although it is called muriate of ammonia, because it is formed when muriatic (hydrochloric) acid and ammonia act on each other. But there is little doubt that these bodies mutually decompose each other, according to the equation, $\text{NH}_3 + \text{HCl} = \text{NH}_4, \text{Cl}$.

The bromide, iodide, and fluoride of ammonium are very similar to the chloride.

ORDER 2.—METALS OF THE ALKALINE EARTHS.

17. BARIUM. $\text{Ba} = 68.7$.

This metal may be obtained with difficulty, by causing the vapor of potassium to pass over baryta (oxide of barium) strongly heated in an iron tube. The potassium is oxidized at the expense of the barium, forming potash, while barium is separated. $\text{BaO} + \text{K} = \text{KO} + \text{Ba}$. Mercury dissolves out the barium, forming a fluid amalgam, and this, if the mercury is distilled off in a small iron retort, leaves the barium.

Barium is a metal of a dark gray color, heavier than oil of vitriol. When exposed to the air, it rapidly absorbs oxygen, forming a white powder, the protoxide of barium or baryta. It is also oxidized by water, hydrogen being liberated.

Protoxide of Barium. $\text{BaO} = 76.718$.

SYN. Baryta.—This alkaline earth occurs in nature combined with carbonic and sulphuric acids. It is best obtained pure by decomposing pure nitrate of baryta, by a continued red-heat, when the nitric acid is destroyed, being expelled as nitrous acid and oxygen, and the baryta left behind: $\text{BaO}, \text{NO}_3 = \text{BaO} + \text{NO}_2 + \text{O}$.

Baryta is a gray porous solid, the Sp. G. of which is about 4.000. It has an acrid alkaline taste, but is much less soluble in water than potash or soda. When sprinkled with water, it slakes, like quick-lime, combining with the water to form a dry, white powder, hydrate of baryta. Great heat attends this combination. Baryta, if exposed to the air, speedily attracts moisture and falls to powder, and the hydrate absorbs carbonic acid from the air, and is converted into carbonate by degrees.

Hydrate of Baryta. $\text{BaO}, \text{HO} = 85.726$.

This compound is formed when dry baryta is slaked with water, as above mentioned. It is a bulky white powder, which dissolves in 3 parts of boiling water, and in about 20 of cold water. The saturated hot solution deposits, on cooling, crystals, which are composed of $\text{BaO}, \text{HO} + 9 \text{ aq}$. The saturated cold solution, which is called barytic water, is a most useful test of the presence of carbonic acid in the air, or in any gas; for with that acid it

instantly produces the insoluble carbonate of baryta, which forms a film, or crust, on the liquid.

A solution of baryta may be formed, extemporaneously, by boiling sulphide of barium in solution with oxide of copper or oxide of lead in excess, and filtering as soon as the liquid gives a white, and not a black precipitate with acetate of lead. The change is as follows: $\text{BaS} + \text{CuO} = \text{BaO} + \text{CuS}$; or $\text{BaS} + \text{PbO} = \text{BaO} + \text{PbS}$. The sulphides of lead and copper, being insoluble, are easily separated by the filter.

Baryta may be recognized, either in the free state, or in its salts, by its giving, with alkaline carbonates, a white precipitate of carbonate, and with sulphuric acid or any soluble sulphate, a white precipitate of sulphate of baryta. The latter is quite insoluble in water and acids: and hence baryta and its salts are much used as tests for sulphuric acid.

Peroxide of Barium. $\text{BaO}_2 = 84.7$.

This oxide is formed either by passing oxygen over baryta at a red-heat, or by sprinkling chlorate of potash on baryta heated to a very low redness, and washing away the soluble part with water. In the latter case it is obtained as a hydrate. It is insoluble in water, and weak acids dissolve it, forming a salt of protoxide; while the oxygen combines with water, forming a peroxide of hydrogen. In fact, the peroxide of barium is only used for the purpose of making that compound.

BARIUM AND CHLORINE.

Chloride of Barium. $\text{BaCl} = 104.17$.

This salt is best obtained by dissolving carbonate of baryta in hydrochloric acid: $\text{BaO}, \text{CO}_2 + \text{HCl} = \text{BaCl} + \text{HO} + \text{CO}_2$. It is also obtained by acting on solution of the sulphide of barium with the same acid: $\text{BaS} + \text{HCl} = \text{BaCl} + \text{HS}$. In the former case carbonic acid gas, in the latter sulphuretted hydrogen gas, is disengaged; and in both the chloride of barium remains dissolved, and, on evaporation, crystallizes in white brilliant tabular crystals, which are composed of $\text{BaCl} + 2 \text{aq}$. A red-heat expels the water of crystallization, and chloride of barium is left.

It is a white solid, soluble in water, and is used in medicine, and very extensively in chemistry, as a test for sulphuric acid, and a means of removing that acid from any solution.

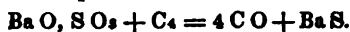
Bromide, iodide, and fluoride of barium are very analogous to the chloride.

BARIUM AND SULPHUR.

Sulphide of Barium. $\text{BaS} = 84.82$.

This useful compound, from which all the other compounds of barium may be obtained, is prepared from the native sulphate of

baryta, or heavy spar, by reducing it to fine powder, mixing it with $\frac{1}{4}$ of its weight of lamp-black (charcoal), and exposing the mixture to a white-heat for two hours in a covered crucible. The following change takes place :



The sulphide of barium dissolves in hot water, forming a colorless solution, which, if exposed to the air, gradually absorbs oxygen, becoming yellow, and is finally converted into hyposulphite of baryta, the latter salt being deposited in hard brilliant crystals. When, in preparing the sulphide, the heat has been insufficient, the sulphuric acid of the sulphate of baryta is entirely deoxidized, the baryta only partially, and we obtain a mixture of baryta and persulphide of barium, Ba S_2 . Thus: $2 (\text{Ba O, S O}_2) + \text{C}_2 = \text{O} + 7 \text{ C O} + \text{Ba O} + \text{Ba S}_2$. This mass, dissolved in hot water, deposits, on cooling, crystals of hydrate of baryta: while the solution, owing to the presence of persulphide, is orange-colored.

Sulphide of barium, from its solubility, and from its being easily decomposed, serves to prepare all the compounds of barium. This, as already stated, if boiled with oxide of copper or of lead, yields hydrate of baryta; and oxide of manganese may be used for the same purpose. With hydrochloric acid it yields chloride of barium, and with nitric or acetic acid it gives rise to nitrate or acetate of baryta: $\text{Ba S} + \text{H O, N O}_2 = \text{H S} + \text{Ba O, N O}_2$. Mixed with carbonate of potash, soda, or ammonia, in solution, it produces insoluble carbonate of baryta, and a soluble sulphide of potassium, sodium and ammonium: $\text{Ba S} + \text{K O, C O}_2 = \text{K S} + \text{Ba O, C O}_2$. From the nitrate pure baryta, and from the carbonate any salt of baryta may be obtained.

All the compounds of barium, except the sulphate, are poisonous.

18. STRONTIUM. $\text{Sr} = 43.8$.

Oxide of Strontium. $\text{Sr O} = 51.813$.

This metal is analogous to barium, but little known. It occurs only as oxide, combined with carbonic acid in strontianite, and with sulphuric acid in celestine. From these minerals the oxide of strontia may be obtained, by processes exactly similar to those described for baryta. Strontia is rather less soluble in water than baryta, but otherwise much resembles it. Indeed it was long confounded with baryta, from which it is distinguished by forming with hydrochloric acid a chloride which crystallizes in needles, and is very deliquescent and soluble in alcohol, to which it gives the property of burning with a crimson flame. The nitrate of strontia is used in making the red fire of the theatres, which is also employed for signal lights.

The chloride and sulphide of strontium are prepared as those of barium, and from the latter, hydrate of strontia and all the

salts of strontia may be prepared. The sulphate of strontia is not absolutely insoluble, like that of baryta, although it is very nearly so.

19. CALCIUM. $\text{Ca} = 20.5$.

Oxide of Calcium. $\text{Ca} = 28.513$.

This metal is little known, but it appears to resemble the two preceding. It is soon oxidized in air or in water, forming the oxide of calcium, or quick-lime.

The oxide, or lime, occurs in great abundance in nature chiefly as carbonate, in the forms of marble, limestone, chalk, and calcareous spar; also as sulphate, in the shape of gypsum and alabaster. Carbonate of lime is the chief ingredient of shells, and phosphate of lime is the earthy part of bones. Lime is found in the ashes of many plants.

Pure lime is easily obtained by igniting white marble or chalk till all the carbonic acid is expelled. The residue is seldom quite white, but combines with water to form a snow-white hydrate (slaked lime). A high temperature is produced in the slaking of lime. Lime is far less soluble in water than baryta or strontia, and cold water dissolves a good deal more lime than hot, about $\frac{1}{100}$. The solution is called lime-water; it tastes acid, and if exposed to the air, is soon covered with a film of carbonate, which forms a crust that at length breaks. Quick-lime, exposed to air, gradually absorbs both water and carbonic acid; but a good red-heat always restores it to the state of quick-lime again. When an excess of hydrate is mixed up with water, it forms a milky-looking fluid, called milk or cream of lime, which is much used for absorbing carbonic acid.

The uses of lime are well known: slaked lime is the chief ingredient in mortar, and lime-water is used in medicine as an antacid. With acids lime forms salts, of which the carbonate, like that of baryta or strontia, is insoluble, the chloride very deliquescent, and the sulphate sparingly soluble, but far from insoluble. Lime and its salts are recognized by forming, with oxalate of ammonia, the very insoluble oxalate of lime. In testing for lime, the solution must be neutral, as an excess of acid dissolves the oxalate.

Chloride of Calcium. $\text{CaCl} = 55.97$.

This salt is formed when carbonate of lime is dissolved in hydrochloric acid, as in preparing carbonic acid gas: $\text{CaO}, \text{CO}_2 + \text{HCl} = \text{CaCl} + \text{HO} + \text{CO}_2$. When the neutral solution is evaporated to the consistence of syrup, it forms, on standing in a cold place, long prisms of crystallized chloride of calcium: $\text{CaCl} + 2\text{HO} + 4\text{aq}$. At 480° these lose the 4 equivalents of water of crystallization, and at a red-heat the other two equivalents of

water. The crystals, when powdered and mixed with snow, liquefy rapidly, and produce intense cold. In every form chloride of calcium has a great attraction for water, and it is much used for drying gases, and in organic analysis for collecting the water, by weighing which the proportion of hydrogen is determined. It also serves to deprive alcohol, ether, and many similar fluids, of water.

The bromide and iodide of calcium are deliquescent salts, Ca Br and Ca I .

Fluoride of Calcium. $\text{Ca F} = 39.24$.

This is a very abundant mineral, occurring chiefly in veins along with lead ore, heavy spar, and quartz. It is well known as fluor, or Derbyshire spar, and crystallizes beautifully in cubes, octahedrons, and tetrahedrons, which are transparent and colorless, or purple, green, brown, or yellow. It also occurs in a massive semi-crystalline form, capable of being cut and polished for ornaments. It is very remarkable that fluoride of calcium is an ingredient of bones in variable quantity. It is said to be found chiefly in the enamel of the teeth, and it is certainly found in variable quantity, but always present, in ancient human bones. It is now said that it is less easily detected in recent bones, owing to the presence of animal matter. It has been found in some bones to the amount of 10 per cent.

The presence of it is detected by treating the mineral or bone, after ignition, with oil of vitriol in a platinum crucible, covered with a waxed plate of glass, having the glass exposed by traces made with a point through the wax. In a short time the traces are so far etched as to be indelible, and very small traces of fluor spar may be thus detected.

Sulphide of Calcium. $\text{Ca S} = 36.62$.

This compound is formed by a process similar to that given for sulphide of barium. Sulphate of lime, mixed with $\frac{1}{2}$ of its weight of charcoal powder, is strongly ignited for an hour or two in a covered crucible: $\text{Ca O}, \text{SO}_3 + \text{C} = 4 \text{CO} + \text{Ca S}$.

It is a nearly white powder, provided no excess of charcoal is present, and is very sparingly soluble in water. When it has been exposed to the sun's rays, it shines in the dark, and is called Canton's phosphorus. When water, lime and sulphur are boiled together, there is formed a yellow or orange solution containing hyposulphite of lime and persulphide of calcium. This liquid, acted on by hydrochloric acid, yields persulphuretted hydrogen. When sulphur and lime are melted together, there is formed a mixture of sulphate of lime and sulphide of calcium.

Phosphide of calcium is obtained in an impure state, by bringing phosphorus in contact with red-hot lime. A brown powder is

formed, which is a mixture of phosphate of lime and phosphide of calcium. When thrown into water it produces spontaneously inflammable phosphuretted hydrogen, along with hypophosphite and phosphate of lime.

20. MAGNESIUM. $Mg = 12.7$.

This metal is obtained by causing the vapor of potassium to come in contact with red-hot chloride of magnesium in a tube. Vivid incandescence takes place, chloride of potassium is formed, and magnesium separated. When the mass is acted on by cold water the chloride dissolves, and the magnesium is left in globules.

Magnesium is silver-white, very brilliant and malleable. It melts at a red-heat; and if heated in air or oxygen, burns vividly, being converted into oxide of magnesium, or magnesia. It does not decompose water, even when boiled with it; and is not oxidized at ordinary temperatures by dry air. Hence it may be preserved far more easily than any of the preceding metals. It dissolves in diluted acids, hydrogen being disengaged.

MAGNESIUM AND OXYGEN.

Oxide of Magnesium. $MgO = 20.713$.

Syn. Magnesia; Calcined Magnesia.—This oxide occurs in nature as carbonate, forming considerable masses of rock in some parts of the world; also as a mixed carbonate of lime and magnesia, under the forms of dolomite and magnesian limestone; and as sulphate of magnesia, or Epsom salts, which occurs in many saline springs.

It is best obtained pure by heating the carbon to redness. Pure or calcined magnesia is a bulky white powder, insoluble in water. It has an earthy taste, and readily unites with acids, neutralizing them, on which account, and because it is in itself mild in its action, it is much used in medicine as an antacid. Magnesia, when precipitated from its salts by an alkali, combines with water, forming a hydrate, MgO, H_2O , which loses its water in a low red-heat. This hydrate is found native, crystallized.

Of the salts of magnesia, the carbonate, like that of the three preceding earths, is insoluble; but the sulphate is very soluble. The solution of this, or any other soluble salt of magnesia, is precipitated by potash, soda, and ammonia, which throw down pure magnesia; and by carbonates of potash and soda, which form carbonate of magnesia. But carbonate of ammonia causes no precipitate, owing to the formation of a soluble double salt; and for the same reason, oxalate of ammonia does not precipitate the salts of magnesia. By this last character magnesia may be distinguished and separated from lime. The most delicate test of magnesia in solutions is to add, first, carbonate of ammonia, and

then phosphate of soda, which then forms an insoluble double phosphate of ammonia and magnesia, in the form of a heavy crystalline powder, slowly formed when the quantity of magnesia is very small.

Besides its uses in medicine, magnesia is a useful ingredient of all fertile soils. The double phosphate of ammonia and magnesia is found in the husk of grain, and in the potato; and phosphate of magnesia is also found in bones. In a soil totally destitute of magnesia, grain does not produce perfect seed, however well the plants may thrive or grow in the stalk or leaf, to which parts magnesia seems not to be essential. Owing to the occurrence of the double phosphate in potatoes, bran, which contains that salt, is a very powerful manure for that crop.

MAGNESIUM WITH CHLORINE, BROMINE, IODINE, AND FLUORINE.

Chloride of Magnesium. $\text{Mg Cl} = 48.17$.

This salt is best formed as follows:—Take two equal portions of hydrochloric acid, and neutralize one with magnesia, the other with ammonia; then mix, evaporate to dryness, and ignite in a covered crucible till the sal ammoniac is dissipated. Fused chloride of magnesium remains, which is poured out on a clean stone, and when solidified kept in a closely-stopped bottle. It is highly deliquescent, and is used for preparing magnesium.

When magnesia acts on hydrochloric acid, they combine, producing hydrochlorate of magnesia, Mg O, H Cl , a rare case. On evaporating the solution to dryness and heating it, hydrochloric acid is expelled and magnesia is left. But when sal ammoniac is added (chloride of ammonium, NH_4, Cl), and the mixture evaporated, chloride of magnesium is formed, and unites with the sal ammoniac, forming a double chloride, $\text{Mg Cl} + \text{NH}_4, \text{Cl}$. When this is ignited, the sal ammoniac is expelled, and chloride of magnesium is left. Chloride of magnesium exists in sea-water, and is found in the mother liquor of the crystals of salt.

The iodide and bromide of magnesium are very soluble; the fluoride is insoluble.

Sulphide of magnesium may be obtained by a method similar to that given for sulphide of barium. When pure, it is a white brittle mass, partially soluble in water.

ORDER 3.—METALS OF THE EARTHS PROPER.

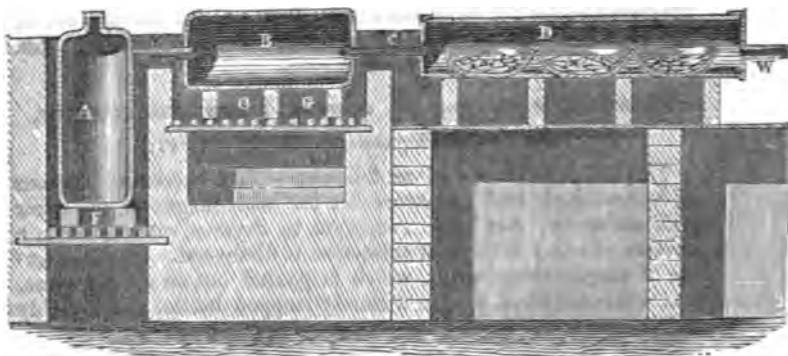
21. ALUMINUM. $\text{Al} = 13.7$.

Mr. Deville has just published a detailed account of the experiments with which he has been engaged for some time, with reference to the production of aluminum, in such a state, and at such a cost, as to be practically applicable for various purposes in the arts.

The method that he adopted is essentially the same as that by which Mr. Wohler obtained this metal—the decomposition of chloride of aluminum by means of an alkaline metal. Sodium was chosen as the decomposing agent, because it is more easily obtained than potassium.

The apparatus used is represented by Fig. 47. It consists of three cylinders, A, B, D, connected by tubes, Y, C, and heated by furnaces, F, G.

Fig. 47.



The chloride of aluminum is introduced into the cylinder A; the sodium is placed in trays, holding about ten pounds each, within the cast-iron cylinder D. The intermediate cylinder, B, contains about a hundred weight of scrap-iron, which serves to separate iron from the vapor of chloride of aluminum, by converting the perchloride of iron into the much less volatile protochloride; it also separates hydrochloric acid and chloride of sulphur.

While the operation is in progress, the tube C is kept at a temperature of 400° to 572° F., and the cylinder D is heated so as to be barely red at the under surface; the reaction between the chloride of aluminum and sodium is attended with so great an evolution of heat that it is sometimes necessary to remove the fire entirely.

Very soon after the reaction has commenced, the chloride of sodium combines with the excess of chloride of aluminum, forming a double salt, which is sufficiently volatile to be carried to the adjoining tray, where the aluminum is eliminated by means of the sodium. The reaction does not commence in one tray, until it has ceased in that which precedes it, and it is at an end when on removing the cover (W) of the cylinder, the last tray is found to contain, in the place of the sodium, a black mass, covered with a colorless liquid which is the double chloride of aluminum and

sodium. The trays are then withdrawn, and replaced by a fresh charge of sodium.

When the contents of the trays are cold they are transferred to crucibles of cast-iron or clay, and heated until completely melted, and the double chloride begins to volatilise. Most frequently the reaction between chloride of aluminum and the sodium is not completed in the cylinder, the sodium being protected by a crust of chloride of sodium; but a double chloride of aluminum and sodium at the top of the trays is always sufficient to insure the perfect absorption of the sodium in the crucible, and the aluminum remains finally in contact with a large excess of chloride of aluminum, which is indispensable for the success of the operation.

When the crucibles are cold, the layer of chloride of sodium is removed from the top, and from the lower part the globules of metal are separated by washing with water; but, unfortunately, the chloride of aluminum is dissolved, and exercises a very destructive action upon the metal, so that the globules obtained are not larger than a pin's head. These are collected, dried, put into a crucible, melted, and run into an ingot.

It is necessary to take especial care in removing from the sodium every particle of carbon which is sometimes mixed with it when badly prepared or insufficiently purified, for otherwise considerable quantities of metallic cyanides or cyanates are formed, which disengage ammonia when brought in contact with water, and cause a further destruction of aluminum. It is also necessary to avoid melting the aluminum while it contains sodium, in which case it takes fire. It is always better to melt it together with some of the double chloride of aluminum and sodium.

The sodium was obtained by heating a mixture of carbonate of soda and carbon in an iron vessel. In operating upon the large scale coal is used, and the proportions of the materials that furnished the best results were—

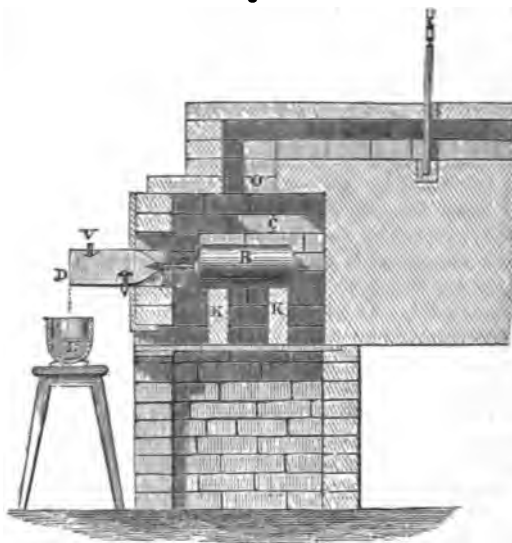
Carbonate of soda (dry)	.	.	.	.	.	30
Coal	.	.	.	.	.	13
Chalk	.	.	.	.	.	5

The characters requisite in this mixture are, that it should not melt at the temperature at which sodium is liberated, and that it should acquire a pasty consistence, so as to remain in contact with the sides of the vessel in which it is heated. The high latent heat of carbonic oxide and of gaseous sodium prevents the iron vessel from being melted.

These substances are dried, powdered, and sifted; then mixed and sifted again, so as to be intimately mixed. The mixture should then be calcined. By this means its volume is considerably reduced, and when the calcination can be effected by the waste heat of a furnace, considerable advantage is gained.

The apparatus used for the preparation of sodium is represented by Fig. 48. The fireplace, C C, of the furnace, shown in action, is lined with firebricks; the bars G are movable, and the flue should be furnished with a well-fitting damper. In the breast of the fur-

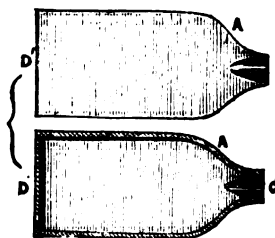
Fig. 48.



nace there is a square opening, P, closed by a plate of cast-iron, with a hole through which the tube T may project.

A mercury bottle, furnished with an iron tube about three inches long, serves as the distillate or vessel. It is supported upon two

Fig. 49.



firebricks, K, about four inches high, and hollowed at the top so as to fit the side of the bottle.

The receiver (Fig. 49) in which the sodium is condensed is made

of two pieces of sheet-iron about one-tenth of an inch thick, A A. One of these pieces is flat, except at the end C, where it is hammered so as to form a semi-cylindrical hollow. The other piece is turned up at the sides, so that, when fitted to the plate A, there is a space of about one-fifth of an inch wide; and a hollow, corresponding to that in the other plate, is hammered at the end, so that together they will form a collar to receive the conical end of the tube T. The edges are filed, so as to fit close, and are kept in their place by two binding screws (V V, Fig. 48.)

When the bottle containing the mixture is placed in the furnace, and the fire made up, a copious evolution of gas commences; and, after about half an hour, a white vapor of carbonate of soda is deposited, which would seem to indicate that the gas contained sodium. However, the receiver must not be attached to the bottle until a cold iron rod passed into the tube T is found to be covered with sodium. When the draught of the furnace is good, the sodium is disengaged rapidly, and the receiver becomes so hot that the condensed metal flows out of the open extremity, D, where it is received in an iron basin, L, containing coal tar naphtha. If, after a time, the receiver should become stopped up, it is replaced by another, previously heated to about 400° or 500° F.

When this operation is well conducted, the sodium obtained is quite pure, and is not accompanied by those carbonaceous substances that are so troublesome in the preparation of potassium.

The operation should be conducted so rapidly that a charge of five pounds of the mixture may be worked off within about two hours.

The temperature requisite for the reduction of carbonate of soda by means of carbon is not so high as has hitherto been supposed; and, according to the opinion of Mr. Rivot, is not greater than that of the retorts in the centre of the zinc furnaces at the Vieille-Montagne.

From the ease with which the operation is conducted, it might be supposed that by increasing the dimensions of all parts of the apparatus used, much larger quantities of sodium may be obtained. However, Mr. Deville has found that there are practical objections to this course; and, after many unsuccessful attempts to work large receivers, he has found that it is preferable to use, with a reduction apparatus five times as large as the mercury bottle, receivers of the same dimensions as in that case.

In operating with large reduction vessels, the calcination of the mixture becomes more advantageous, if not indispensable. When the operation is made continuous, the mixture may be calcined as it is required, and introduced into the reduction vessel red hot.

The vessels used for the continuous operation are drawn iron tubes, four feet long, six inches internal diameter, and about $\frac{1}{2}$ inch thick. One end is closed by a $\frac{3}{4}$ inch plate of iron, with a hole near one side, into which is screwed the discharge tube that fits into the

receiver. The other end of the cylinder is closed by a movable iron plug, O, with a handle; it is at this end that the mixture is introduced.

These tubes must be covered with a refractory lute, and an exterior envelope of baked clay, so as to be entirely protected from the direct action of the fire.

The furnace in which the operation was conducted was an ordinary reverberatory furnace, in which the fireplace was divided into two parts by a small wall upon which the cylinders rested in the middle, while their ends were level with the outer walls of the furnace. The fuel was introduced through two lateral openings kept closed by the fuel upon a shelf outside the furnace. These openings are at such a height above the bars of the furnace, that there would be a space of a foot between the fuel and the tubes. The fuel used was a mixture of equal parts coke and coal.

Upon the hearth of the furnace, the mixture for the preparation of sodium may be calcined in crucibles; and, when the furnace is worked continuously, the temperature becomes sufficiently high for working some reduction cylinders upon the hearth.

Mr. Deville did not find the furnace which he used very well adapted for the production of potassium, and considers that it would be better if constructed after the manner of a puddling furnace described by M. Dumas. He is of opinion that there is no question as to the practicability of the production of sodium by a continuous operation, if the furnace is constructed in a suitable manner.

The chloride of aluminum was prepared by the method recommended by Gay-Lussac and Thénard. Alumina, quite free from iron, was mixed with 40 per cent. carbon, and a small quantity of coal, made into a paste, and decomposed at a red heat. The compact mass was broken into fragments, and introduced into an earthen retort. This was placed in a furnace, and heated in redness, while a stream of dry chlorine was passed through the contents. At first a considerable amount of water was evolved from the aluminous carbon, which is very hygroscopic. When the chloride of aluminum began to appear, an earthen funnel was fitted to the neck of the retort by means of asbestos and clay, and a bell-shaped vessel fitted in the same manner to the rim of the funnel. The chloride of aluminum condenses in this receiver, and, however rapid the stream of chlorine may be during the chief part of the operation, it is so completely absorbed by the aluminous carbon that the carbonic oxide which escapes does not give any indication of chlorine. However, it contains a little chloride of silicium, arising from the action of the chlorine and carbon upon the material of the retort; also, some aluminum, and, perhaps, some chloro-carbonic acid. When the receiver is full of chloride of aluminum, it is removed, and replaced by another, and so on till the operation is finished.

The amount of chloride of aluminum obtained from 10 pounds

of alumina was rather more than 20 pounds. The carbonaceous residue in the retort contained some alumina, a considerable amount of alkaline chlorides, and of the double chloride of aluminum and potassium. The residue was washed, mixed with a fresh quantity of alumina, and subjected to the same treatment.

In working the process upon a large scale, pitch was used as the carbonaceous substance; instead of the clay retort, an ordinary gas retort, and, instead of the bell vessel, a small brick chamber, covered with glazed earthenware.

The ammoniacal alum is calcined upon the hearth of the reverberatory furnace, in which the sodium is prepared. After having been heated to redness, it is powdered and mixed with coal tar. The paste is introduced into crucibles carefully covered, and placed in the reverberatory furnace. When the evolution of vapor ceases, the crucibles are removed, and, when it is possible, the aluminous carbon is used while hot.

The stream of chlorine should be so adjusted as to avoid loss either by escaping from the joints of the apparatus or by being carried up the chimney.

Before commencing the operation, every part of the apparatus should be rendered perfectly dry by heating it.

With regard to the utilisation of aluminum in the arts, Mr. Deville considers that the necessary condition is its production at a cost considerably less than that of silver. Owing to the difference in density, if aluminum and silver were of the same value, aluminum would be only one-fourth as dear as an equal volume of silver; and, for equal masses, the rigidity of aluminum is much greater than that of silver.

The materials with which aluminum is produced, even by the methods hitherto employed, are all obtainable at a small cost. Thus to produce about half a hundred-weight of aluminum, there would be required

Chlorine	237 pounds, costing .	\$.13 50
Alumina	114 " "	. 3 25
Carbonate of Soda, 350 "	" "	. 13 25
		<hr/> \$30 00

Which would render the cost of the materials for producing a pound of aluminum about fifty cents.

With regard to the actual cost of the production of aluminum in these experiments, Mr. Deville states that he is unable to speak decisively; and that the means of working at his disposal were so defective that the experiments made could not furnish an exact indication with regard to this particular.

However, he states that he was able to produce sodium at a cost of eighty-seven cents per pound, including only the cost of materi-

als, labor, fuel, and retorts. The quantity of sodium made by Mr. Deville at the Javel Works was from 330 to 440 pounds.

The cost of the chloride of aluminum was about 37 cents a pound. Alumina was prepared from ammoniacal alum, and cost as much as fifty cents a pound. The quantity of chloride of aluminum made was from 1100 to 1320 pounds.

ALUMINUM AND OXYGEN.

Sesquioxide of Aluminum. $\text{Al}_2\text{O}_3 = 51.539$.

Syn. Alumina; Pure Clay.—This earth is very abundant in nature. It occurs crystallized as the sapphire and ruby; in a crystalline but more massive form, as corundum or emery; and as the chief ingredient of all clays, and of most slaty rocks, from which, indeed, clays are derived. Pipe-clay is the purest clay, but is not pure alumina, although approaching to it.

Pure alumina is best prepared as follows:—A solution of alum is precipitated by an excess of chloride of barium, by which means the sulphuric acid is separated, and chloride of aluminum is left in solution with the chloride of potassium and the excess of chloride of barium. $\text{Alum} (\text{K O}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3 \text{SO}_3)$ with 4 Ba Cl yields 4 $(\text{Ba O}, \text{SO}_3) + \text{K Cl} + \text{Al}_2\text{Cl}_3$. On evaporation, water is decomposed, and hydrochlorate of alumina is formed, $\text{Al}_2\text{Cl}_3 + 8 \text{H O} = \text{Al}_2\text{O}_3, 3 \text{H Cl}$. When the dry mass is ignited, the hydrochloric acid is expelled, and the alumina is left with the chlorides of potassium and barium, which are removed by water.

Pure alumina is a fine white powder, quite unalterable in the fire. When precipitated from its solution in acids by alkalies, it forms a very bulky gelatinous hydrate, which, when dried at 60° , is $\text{Al}_2\text{O}_3, 6 \text{H O}$; if dried at 100° it becomes $\text{Al}_2\text{O}_3, 3 \text{H O}$. Dry or anhydrous alumina, mixed with water, forms a plastic mass, which admits of being moulded. This property is given to clay by the presence of alumina, and is the foundation of the art of making porcelain or earthenware.

Alumina, after ignition, is almost insoluble in acids; but the hydrate readily dissolves in all strong acids, forming salts which have a peculiar astringent taste.

Alumina is precipitated, as hydrate, from its solutions by potash, soda, ammonia, and their carbonates; but the precipitate readily dissolves in an excess of the two first. Sulphide of ammonium, which precipitates none of the previously described metallic oxides, causes in solutions of alumina a precipitate, which, however, is not a sulphide, but the hydrate of alumina precipitated by the ammonia of the test.

Besides the use of alumina in pottery, it is much used in dyeing and calico-printing, from its attraction for vegetable coloring matters, and for the fibre of cloth. It forms a bond or union between the cloth and the dye, and fixes the latter on the former. It is

said, in this, to act as a mordant, and is most generally used in the form of alum or acetate of alumina. When solution of alum is mixed with a coloring matter, and the alumina then precipitated by an alkali, the hydrate carries with it all the coloring matter, or the greater part of it, and forms what is called a lake. The water color termed lake is merely a lake made with some pink dye stuff, such as madder or logwood. Carmine is a lake of cochineal.

ALUMINUM AND CHLORINE.

Sesquichloride of Aluminum. $\text{Al}_2 \text{Cl}_3 = 133.81$.

This compound is prepared by passing chlorine gas over a mixture of alumina and charcoal, heated to redness in a tube. The chloride sublimes into the cold part of the apparatus. It forms a volatile crystalline mass, colorless or slightly yellow. It fumes in the air, and dissolves in water with much heat. It appears at first to combine with the water, forming a hydrated chloride, $\text{Al}_2 \text{Cl}_3, 3 \text{H}_2 \text{O}$; but on heating this, hydrochloric acid is expelled, and alumina is left, $\text{Al}_2 \text{Cl}_3, 3 \text{H}_2 \text{O} = \text{Al}_2 \text{O}_3, 3 \text{HCl}$. The chloride is used for the preparation of aluminum.

The sulphide of aluminum is formed when sulphur is dropped on red-hot aluminum. It is a dark gray mass, which decomposes water, forming sulphuretted hydrogen and alumina, and hence its composition must be $\text{Al}_2 \text{S}_3$. If so, we have $\text{Al}_2 \text{S}_3 + 3 \text{H}_2 \text{O} = \text{Al}_2 \text{O}_3 + 3 \text{H}_2 \text{S}$. Similar compounds are formed with phosphorous and selenium.

22. GLUCINUM. 23. YTTRIUM. 24. THORIUM. 25. ZIRCONIUM.

These metals, or rather their oxides, are all so rare as not to admit of any useful application. The oxides, which are glucina, yttria, thorina, and zirconia, only occur in a few rare minerals.

Glucina occurs in the emerald and the beryl. Its composition is analogous to that of alumina; and its formula is $\text{G}_2 \text{O}_3$. It is a white powder, insoluble in water, soluble in acids, forming salts, which have a sweetish taste. It resembles alumina very much, but differs from it in being soluble in solution of carbonate of ammonia. The metal, which may be obtained, like aluminum, from the chloride, burns with amazing splendor when heated in oxygen.

Yttria, the oxide of yttrium, occurs in gadolinite, in yttrocerite, and in yttrantalite. The pure earth is a white powder, which dissolves in acids, forming sweetish salts, from which yttria is precipitated by alkalies; but is not, like alumina and glucina, redissolved by excess of potash or soda. It is, moreover, precipitated by ferrocyanide of potassium, which these earths are not. Yttria seems to be a protoxide of yttrium, $\text{Y}_2 \text{O}_3$. The salts of yttria have often an amethyst color; but the recent researches of Mosander seem to show that this is owing to the presence of the oxide of one

of the new metals detected by him, which accompany yttrium. It is probable that pure yttria is not yet known.

Thorina is still more rare, and has only been found in one mineral — thorite. It is a white powder, resembling yttria. The metal, thorium, burns in air or oxygen, when heated, with great splendor. It also burns with sulphur and phosphorus, as do the two preceding metals.

Zirconia is found in the zircon or hyacinth. It resembles alumina in appearance. It differs from all the preceding earths in being precipitated as an insoluble subsulphate, when solutions of its salts are boiled with sulphate of potash. The metal, zirconium, resembles aluminum. The oxide is believed to be a sesquioxide $Zr_2 O_3$.

METALS.—CLASS II.

ORDER 1.—METALS, THE PROTOXIDES OF WHICH ARE POWERFUL BASES, BUT WHICH DO NOT DECOMPOSE WATER, UNLESS WITH THE AID OF A RED-HEAT.

26. MANGANESE. $Mn = 27.7$.

This metal occurs in considerable abundance, chiefly as deutoxide or peroxide $Mn O_2$, which is much used in the arts and in chemical manufactures, as well as in the laboratory. The metal is obtained by making oxide of manganese into a paste with oil, and exposing this paste to a strong white-heat in a covered crucible. If the heat be high enough, a button of the metal is obtained.

It is hard, brittle, very difficultly fusible metal, of a grayish-white color, Sp. G. 8.013. It tarnishes on exposure to the air, and is rapidly oxidized when heated. It decomposes water rapidly at a red-heat, hydrogen being disengaged. As a metal, it is not applied to any useful purpose.

MANGANESE AND OXYGEN.

a. Protoxide of Manganese. $Mn O = 35.713$.

This oxide is obtained when the peroxide is acted on by hydrogen gas at a red-heat. But the best method is to heat to redness a mixture of 1 part of dry chloride of manganese, 1 part of sal ammoniac, and 2 parts of dry carbonate of soda. The chloride acts on the soda, $Mn Cl + Na O = Mn O + Na Cl$; forming oxide of manganese and chloride of sodium; while the carbonic acid escapes as gas; the sal ammoniac is also expelled, and its vapor serves merely to exclude the oxygen of the atmosphere. From the fused mass, water extracts the chloride of sodium; and leaves the protoxide of manganese undissolved.

It is a powder of a pale grass-green color, which, if prepared by hydrogen at a low red-heat, soon attracts oxygen from the air and becomes brown. If it has been made, however, at an elevated temperature, especially by the second process, it is more compact, and keeps tolerably well. When heated in the air, it takes fire and burns.

Protoxide of manganese is a powerful base, neutralizing acids and forming salts, which are either colorless or have a tinge of flesh color. Its solutions give, with caustic alkalies, a precipitate of hydrate, which is at first white, but soon absorbs oxygen and becomes brown; with carbonated alkalies, a white precipitate of carbonate of manganese, which retains its whiteness till it is dried, when it becomes generally slightly fawn-colored. Sulphide of ammonium causes a flesh-colored precipitate of sulphide of manganese, which, in the air, absorbs oxygen and becomes brown. Chloride of soda or bleaching liquor causes a bulky dark brown precipitate of hydrated peroxide. The two last tests are characteristic. Ferrocyanide of potassium gives a white precipitate. All the salts of protoxide of manganese may easily be prepared from the carbonate, which again is most economically made from the chloride, the preparation of which will be described below. The sulphate is used in calico-printing.

b. Sesquioxide of Manganese. $Mn_2O_3 = 79.439$.

This oxide is left behind when the peroxide is ignited in preparing oxygen gas: $2 MnO_2 = Mn_2O_3 + O$. It is a dark brown powder, very similar to the peroxide, but rather lighter in color, and yielding no oxygen when ignited. It is a feeble base, and is only known to combine with sulphuric acid, forming an amethyst-colored solution of sesquisulphate. With sulphates of potash and ammonia this salt forms manganese alums, which crystallize in dark purple octahedrons. When heated with sulphuric acid, it yields oxygen, and with hydrochloric acid, chlorine; but less of either than the peroxide, (which see.) As some specimens of peroxide are, naturally or accidentally, mixed with sesquioxide, the manufacturer finds it a source of inconvenience and loss. It occurs in a pure state as braunite, and combined with baryta in psilomelan. Its hydrate is the mineral manganite. Its powder is dark brown.

c. Hyperoxide or Peroxide of Manganese. $MnO_2 = 43.726$.

Syn. Deutoxide of Manganese. — This oxide is found in considerable abundance, and is known in the mineral kingdom as pyrolusite. It generally assumes the form of a black shining mass composed of radiated groups of acicular crystals; also in distinct crystals, which are right rhombic prisms; and in the compact and even earthy state. Its powder is black. When heated to redness,

it loses one-fourth of its oxygen, leaving sesquioxide: $2 \text{MnO}_2 = \text{Mn}_2\text{O}_3 + \text{O}$. In a white-heat it is said to lose half its oxygen, leaving protoxide. Heated with oil of vitriol, it forms sulphate of protoxide, and half the oxygen is expelled: $\text{MnO}_2 + \text{H}_2\text{O}, \text{SO}_2 = (\text{MnO}, \text{H}_2\text{O}, \text{SO}_2) + \text{O}$. With hydrochloric acid it yields chlorine, chloride of manganese, and water: $\text{MnO}_2 + 2 \text{HCl} = \text{Cl} + \text{MnCl} + 2 \text{H}_2\text{O}$. It also yields chlorine when heated with common salt and sulphuric acid; and this is the process commonly used by the manufacturers of bleaching-powder: $\text{MnO}_2 + \text{NaCl} + 2 \text{H}_2\text{O}, \text{SO}_2 = (\text{MnO}, \text{H}_2\text{O}, \text{SO}_2) + (\text{NaO}, \text{H}_2\text{O}, \text{SO}_2) + \text{Cl}$.

It is further used in glass-making to destroy the color given to the glass by protoxide of iron, which it converts into peroxide; in larger proportion, to give glass an amethyst color; and in numerous operations in the laboratory, as a convenient oxidizing agent.

With water, peroxide of manganese forms a hydrate, $\text{MnO}_2 \cdot \text{H}_2\text{O}$, which is obtained when salts of the protoxide are acted on by bleaching liquor, or when the acids of manganese are spontaneously decomposed. It is a beautiful brown powder, which is decomposed by heat.

d. Manganic Acid. $\text{MnO}_2 = 51.739$.

This acid has not been isolated. It is only known in combination with bases, especially potash, in which state it forms the chief ingredient of the mass called chameleon mineral, formed by igniting peroxide of manganese strongly with nitre, or, still better, by heating a mixture of peroxide, chlorate of potash, and caustic potash. A dark green mass is formed, which is the chameleon mineral. The green color is a property of manganic acid and all its salts. The peroxide obtains oxygen from the nitre or chlorate of potash, and the acid, when formed, combines with the potash. Water dissolves the manganate of potash, forming a splendid emerald-green solution, which very soon begins to change color, and passes through bottle-green, blue, and purple, to a fine crimson red, hydrated peroxide of manganese being at the same time deposited. The red color belongs to a salt of the next acid, permanganic acid, (see below). The salts of manganic acid are decomposed if kept in solution, depositing hydrated peroxide.

e. Permanganic Acid. $\text{Mn}_2\text{O}_7 = 111.491$.

The salt of this acid with potash, permanganate of potash, is formed, when the chameleon mineral (see above) is dissolved in hot water. The green color of the manganate changes to red, while hydrated peroxide separates. 3 eqs. manganate of potash give rise to 1 eq. permanganate, 1 of peroxide, and 2 of free potash: $3(\text{KO}, \text{MnO}_2) = \text{Mn}_2\text{O}_7 + (\text{K}_2\text{O}, \text{Mn}_2\text{O}_7) + 2 \text{KO}$. When the red solution is sufficiently evaporated, it deposits small dark bronze-colored crystals of permanganate of potash.

This salt is more permanent than the manganate; but when we attempt to isolate the acid, it is rapidly decomposed, yielding hydrated peroxide and oxygen gas: $\text{Mn}_2\text{O}_7 = 2\text{MnO}_2 + \text{O}_2$.

The name of chameleon mineral was given to the compound above described from its singular changes of color. Both the above acids possess and communicate to their salts very beautiful colors; but they cannot be used in dyeing, &c., because these acids are so easily decomposed, especially by the contact of organic matter. They ought to be filtered through asbestos when they require filtration.

f. Red Oxide of Manganese. $\text{Mn}_2\text{O}_3 = 115.152$.

This oxide occurs in nature, and may be obtained when any other oxide of manganese is strongly ignited in an open crucible. It is very permanent in composition; its color is reddish-brown. It is not supposed to be an independent oxide of the metal, but rather a compound of two other oxides. It may be either $\text{MnO} + \text{Mn}_2\text{O}_3$, or $\text{MnO}_2 + 2\text{MnO}$, and it is not easy to say which.

g. Varvicite. $\text{Mn}_4\text{O}_7 = 166.8$.

This is another oxide, found native in Warwickshire, whence the name. It resembles the peroxide, but is really distinct. It is probably a compound of two others, $\text{Mn}_2\text{O}_3 + 2\text{MnO}_2$.

MANGANESE AND CHLORINE.

a. Protochloride of Manganese. $\text{MnCl} = 63.15$.

This salt is best obtained by the following process:—The solution formed in the preparation of chlorine by means of peroxide of manganese and hydrochloric acid, which is generally a mixture of chloride of manganese and more or less perchloride of iron, is first rendered neutral by gently evaporating it to dryness. It is then redissolved, and a portion of it precipitated by carbonate of soda, which throws down a mixture of peroxide of iron and carbonate of manganese: $\text{MnCl} + \text{Fe}_2\text{Cl}_3$, acted on by $4(\text{NaO}, \text{CO}_2)$ yield $(\text{MnO}, \text{CO}_2 + \text{Fe}_2\text{O}_3 + 4\text{NaCl} + 3\text{CO}_2)$. The precipitate is well washed, and then boiled with the rest of the solution, when the oxide of manganese in the precipitate acts on the perchloride of iron in the solution, producing chloride of manganese, which dissolves, and peroxide of iron, which separates: $3(\text{MnO}, \text{CO}_2) + \text{Fe}_2\text{Cl}_3 = 3\text{MnCl} + \text{Fe}_2\text{O}_3 + 3\text{CO}_2$. The filtered liquid is free from iron, if we have hit the proportion right; if not, a second operation with a smaller portion of the liquid will complete the purification. The pure solution is evaporated to dryness in a retort, and there fused. On cooling, the protochloride forms a pink crystalline mass. Iron is the ordinary impurity to be removed; but if other metals be present, they are to be got rid of by appropriate means. Thus, if cobalt and nickel are present,

which they generally are in small quantity, the addition of sulphide of ammonium, as long as it causes a dark precipitate, or till it produces the pure flesh-color characteristic of manganese, will remove them. The chloride of manganese is used for preparing, by the action of an alkaline carbonate, pure carbonate of manganese, from which all other salts of manganese may be obtained.

b. Perchloride of Manganese. $\text{Mn}_2 \text{Cl}_7 = 303.19$.

This compound, which corresponds to the permanganic acid, is formed, according to Dumas and Wöhler, when permanganate of potash is heated along with common salt and sulphuric acid: $\text{K O}, \text{Mn}_2 \text{O}_7 + 7 \text{Na Cl} + 8 \text{S O}_2 = \text{K O}, \text{S O}_2 + 7 (\text{Na O}, \text{S O}_2) + \text{Mn}_2 \text{Cl}_7$. It is a greenish-brown volatile liquid, which is instantly decomposed by contact with moist air, forming a dense cloud of a pink color. Here water is acted on, and the products are hydrochloric and permanganic acids: $\text{Mn}_2 \text{Cl}_7 + 7 \text{H O} = \text{Mn}_2 \text{O}_7 + 7 \text{H Cl}$.

c. Perfluoride of Manganese. $\text{Mn}_2 \text{F}_7 = 186.46$.

When mineral chameleon (or better, permanganate of potash) is acted on by sulphuric acid and fluoride of calcium (fluor-spar) with the aid of heat, a greenish-yellow gas or vapor is disengaged, which, with moist air, instantly becomes red. It acts powerfully on glass. Its composition seems to correspond to that of the preceding compound, and its production is to be explained in the same way, substituting fluoride of calcium for chloride of sodium.—(Wöhler.)

d. Protosulphide of Manganese. $\text{Mn S} = 43.79$.

This compound is found native. It may be formed by passing a current of sulphuretted hydrogen over sulphate of manganese at a red-heat. The sulphuric acid of the sulphate is expelled, and the protoxide is acted on by the sulphuretted hydrogen: $\text{Mn O} + \text{H S} = \text{Mn S} + \text{H O}$. It is nearly black in color, and dissolves readily in dilute hydrochloric and other acids, with disengagement of sulphuretted hydrogen: $\text{Mn S} + \text{H Cl} = \text{Mn Cl} + \text{H S}$. The flesh-colored precipitate formed in salts of protoxide of manganese by sulphide of ammonium, or any other soluble sulphide, is a hydrated protosulphide of manganese: $\text{Mn S}, \text{H O}$.

27. IRON. $\text{Fe} = 28$.

This important and useful metal occurs very abundantly in nature. It is occasionally found in the uncombined state in masses, most probably of meteoric origin: but its most common form is that of oxide, frequently uncombined, frequently also combined with carbonic acid. It is found, likewise, abundantly as sulphide. There is hardly a rock, a soil, or a mineral which does

not contain some proportion, generally a small one, of oxide of iron : and the carbonate is a frequent ingredient in mineral waters, which are then termed chalybeate waters.

The chief ores of iron are—1. Clay iron stone, which is a more or less pure carbonate of protoxide, generally containing carbonates of lime and magnesia ; it accompanies coal beds both in England and in Scotland. 2. Red hematite, which is pure peroxide or sesquioxide of iron ; and brown hematite, which is hydrated peroxide. 3. Black or magnetic oxide of iron.

From its ores iron is obtained by heating them in furnaces, in the upper part of which the ores are stratified with coal, lime, and sandstone. The carbon of the coal, at a red-heat, reduces the iron to the state of metal, while the sand and lime act as a flux, and form a liquid slag, through which the melted iron falls to the lower part of the furnace, where it is drawn off. The slag is drawn off separately after the iron, and on cooling is found to be a mixture of silicates of lime and magnesia with a little iron.

The iron thus obtained, which is called pig iron or cast iron, is not pure, containing some unreduced ore, or earthy matters, and a good deal of combined carbon. It is far more fusible than pure iron, but also far more brittle. To convert it into pure or malleable iron, it is melted and exposed to a current of air, which gradually burns off the carbon. The mass is well stirred, and the other impurities rise to the surface as slag or dross. By degrees the metal becomes less fusible, and the heat must be increased, till at last, with the strongest heat, the metal continues solid. It is then well hammered while hot, by which it is still further purified, and rendered more dense. It is not yet absolutely pure, containing about $\frac{1}{4}$ per cent. of carbon, and a trace of silicon. A very good test of the purity of iron is its ductility. Unless very pure, it cannot be drawn out into fine wire.

If perfectly pure iron is wanted, the filings of malleable iron should be fused with one-fourth their weight of black oxide of iron, and some green glass to act as a flux. Or pure oxide of iron may be reduced to the metallic state by passing a current of hydrogen gas over it at a red-heat. The metal remains as a spongy mass.

Pure iron has a gray color, and strong lustre when polished. It is very ductile, moderately malleable, and remarkably tenacious. It is hard at common temperatures, but at a red-heat it is so soft that it may be beaten into any form, and even admits of being welded ; that is, two pieces of iron being heated red-hot, may be by hammering, so incorporated into one, that no joining is perceptible. Its Sp. G. is 7.7. It is very infusible, requiring the very highest temperature of a wind furnace to melt it.

Iron is attracted by the magnet, and may itself be rendered permanently magnetic by various means.

The attraction of iron for oxygen is very powerful, and when exposed to air and moisture it rusts rapidly, forming oxide of iron. When heated to redness in air, iron is very quickly covered with a crust of black oxide, which scales off under the hammer. If heated to redness in oxygen, or to whiteness in the air, it burns with vivid scintillations. To secure the result in the air, the white-hot metal must be exposed to a current of air from a bellows, or rapidly whirled round. Iron decomposes water rapidly at a red-heat.

IRON AND OXYGEN.

a. Protoxide of Iron. $\text{Fe O} = 36.013$.

This oxide is a powerful base, almost unknown in a separate state, owing to its tendency to attract an additional quantity of oxygen. It combines with acids, forming salts, which have generally a pale bluish-green color, although some are colorless. Several of these salts are of great importance in medicine and in the arts, particularly the sulphate of iron, or green vitriol.

The solutions of these salts give with alkalies, when no trace of peroxide is present, a bulky white precipitate of hydrated protoxide of iron, which soon becomes green, and lastly brown, being converted into peroxide by absorbing oxygen from the air. They give a similar precipitate, not more permanent, with carbonated alkalies, which at first is hydrated carbonate of protoxide; but as oxygen is absorbed, the carbonic acid is given off, peroxide of iron having no affinity for that acid. With ferrocyanide of potassium they give a pale blue, or rather a white precipitate, which gradually becomes dark blue; and with ferridcyanide of potassium (red prussiate) a deep blue precipitate of Prussian blue. These salts are not affected by sulphuretted hydrogen, sulphocyanide of potassium, meconic acid, or gallic acid. Sulphide of ammonium, and soluble sulphides produce a black precipitate of sulphide of iron.

The salts of protoxide of iron, for the most part, attract oxygen from the air and from other bodies, passing into salts of the peroxide. Hence they act in some cases as deoxidizing agents. Gold is completely reduced from its solutions by protosulphate of iron.

b. Sesquioxide of Iron. $\text{Fe}_2 \text{O}_3 = 80.039$.

Syn. Peroxide of Iron.—This oxide is found native, as red hematite and specular iron ore; and hydrated, as brown hematite. It may be prepared artificially by calcining pure, dried green vitriol; when the protoxide is oxidized at the expense of the sulphuric acid, and water, along with sulphuric and sulphurous acids, is expelled: $2 (\text{Fe O}, \text{H O}, \text{S O}_3) = \text{Fe}_2 \text{O}_3 + 2 \text{H O} + \text{S O}_2 + \text{S O}_3$. A red powder is left, which is peroxide of iron, and in this form it is used for polishing plate, as jewelers' rouge, or colcothar

of vitriol. Hydrated peroxide of iron is obtained by precipitating a solution of persulphate of iron or perchloride of iron by an alkali, whether caustic or carbonated. When protosulphate of iron is precipitated by an alkaline carbonate, the precipitated protocarbonate, during the process of washing and drying, loses its carbonic acid, and attracts oxygen, becoming hydrated peroxide. This, when dry, is a brown powder, used in medicine under the erroneous name of carbonate of iron. In the moist state it is the only known antidote to arsenious acid.

Peroxide of iron is not magnetic. It is a base, although not a powerful one, forming, with acids, salts which are either yellow, brown or red. The solutions of such salts or persalts of iron, as they are called, are very easily recognized. They give, with caustic or carbonated alkalies, a brown precipitate of hydrated peroxide; with ferrocyanide of potassium, a deep Prussian blue; with ferridcyanide of potassium, no precipitate; with sulphocyanide of potassium, or with meconic acid, a blood-red color; and with tannic acid (or tannine) and gallic acid, a bluish-black color (ink.) Sulphuretted hydrogen causes a white precipitate of sulphur, while the peroxide is reduced to protoxide; sulphide of ammonium causes a black precipitate of sulphide of iron. These tests are so delicate and so uniform, especially those of ferrocyanide of potassium, sulphocyanide of potassium, and tannic acid, or infusion of galls, that it is always best, in testing for iron, to convert any protoxide that may be present into peroxide; which is easily done by boiling the solution with a little nitric acid.

c. Magnetic Oxide of Iron, $\text{Fe}_3\text{O}_4 = 116.052$; and $\text{Fe}_4\text{O}_3 = 152.065$.

This oxide is a native magnet, or lodestone, which is a heavy black mineral, strongly attracting iron filings, or steel. It is believed to be composed of protoxide and peroxide, and the native magnet is generally supposed to be $\text{Fe}_3\text{O}_4 = \text{FeO} + \text{Fe}_2\text{O}_3$. There is reason, however, to believe that another kind of magnetic oxide exists, which is $\text{Fe}_4\text{O}_3 = 2\text{FeO} + \text{Fe}_2\text{O}_3$. At all events, both of these compounds may be formed artificially, and both are magnetic as well as permanent; not absorbing oxygen, or passing into peroxide. To prepare the former, take 2 parts of green vitriol; dissolve it in water, and convert it into persulphate by boiling with nitric acid; then mix the solution with the solution of 1 part of the unaltered green vitriol, and precipitate the hot liquid by ammonia. A green precipitate falls, which is to be washed and dried. The second magnetic oxide is prepared in the same way, only converting into persulphate 1 part of green vitriol instead of 2 parts. The precipitate is black, if made in the liquid while hot. It is evident that in the latter case the quantity of iron, in the forms of protoxide and peroxide will be equal: in the former the quantity of iron in the peroxide will be double that in the protoxide,

as to yield the above formulæ. Magnetic oxide of iron is also formed when iron is heated red-hot and hammered. The black scales which separate (smithy ashes) are magnetic. The same oxide is produced when the vapor of water is passed over iron at a red-heat, hydrogen being disengaged. It is used in medicine.

When black oxide of iron is dissolved in acids, both protoxide and peroxide are present. The latter may be precipitated by digestion with carbonate of lime, after which the former can be detected in solution.

d. Ferric Acid. $\text{Fe O}_3 = 52.039$.

Recent researches have established the existence of this compound, which corresponds to manganic acid. It is very easily decomposed, and is hardly known in a separate state. Ferrate of potash may be obtained in solution by igniting oxide of iron with nitre, or by passing chlorine through aqua potassæ in which peroxide of iron is suspended. The solution has a very fine and intense purple color, which, however, is not very permanent.

IRON AND CHLORINE.

a. Protochloride of Iron. $\text{Fe Cl} = 63.47$.

This compound is formed when dry hydrochloric acid gas is passed over iron heated to redness, hydrogen gas being disengaged: $\text{Fe} + \text{H Cl} = \text{Fe Cl} + \text{H}$. It appears as a white crystalline solid, volatile in a very high temperature. It dissolves readily in water, forming a pale green solution, which yields on evaporation crystals of the same color. These contain water of crystallization. The characters of this solution, its color, taste, and reactions, are so exactly those of a solution of a salt of protoxide, that there is good reason to conclude that the chloride, in dissolving, decomposes water, forming protoxide of iron and hydrochloric acid.

b. Perchloride of Iron. $\text{Fe}_2 \text{ Cl}_3 = 162.35$.

Syn. Sesquichloride of Iron; Permuriate of Iron.—It is formed when chlorine gas is passed over iron heated to a temperature below redness, when it appears as red iridescent scales, volatile at a temperature a little beyond 212° , and soluble in water, alcohol, and ether. A solution of the perchloride is easily obtained by dissolving peroxide of iron in hydrochloric acid: $\text{Fe}_2 \text{ O}_3 + 3 \text{ H Cl} = \text{Fe}_2 \text{ Cl}_3 + 3 \text{ H O}$. When evaporated to the consistence of syrup, and cooled, it forms red crystals, which contain water of crystallization. When heated, they are partly decomposed, peroxide being formed, and hydrochloric acid passing off, in consequence of the action between perchloride of iron and water. As perchloride of iron is a volcanic product, it is probably in this

way that the crystals of peroxide, found in volcanic districts, have been formed. Perchloride of iron is much used in medicine.

IRON AND IODINE.

a. Protoiodide of Iron. $\text{Fe I} = 154.3$.

When iron filings and iodine, in atomic proportions, are brought in contact under water, they rapidly combine, with considerable heat, and the resulting iodide dissolves in the water. The whole is boiled with a slight excess of iron for a short time, and the pale green filtered solution rapidly boiled down in a Florence flask, till on cooling it becomes solid. The solid mass of iodide is broken up, and kept in very closely-stopped bottles. It forms a dark gray crystalline mass, which is very soluble in water, and forms a pale green solution; the solution, which is much used in medicine, attracts oxygen rapidly from the atmosphere, and is decomposed, iodine escaping, and peroxide being deposited. It is, therefore, necessary to prepare it extemporaneously, or to keep it in small, tightly-corked bottles, with a portion of clean iron wire in each.

b. Periodide of Iron. $\text{Fe}_2 \text{I}_3 = 434.9$.

This compound is made by causing an excess of iodide to act on iron wire, and subliming the dry mass left after gently evaporating to dryness. It is a volatile deliquescent body, of a red color, soluble in water and alcohol.

The bromides of iron are analagous to the chlorides and iodides; and the fluorides correspond in composition, but are sparingly soluble in water.

IRON AND SULPHUR.

a. Protosulphide of Iron. $\text{Fe S} = 44.12$.

This sulphide is prepared by heating iron filings with sulphur in atomic proportions, when they combine with evolution of heat and light. Or a bar of iron may be heated to whiteness in a forge, and a stick of roll sulphur applied to the hot metal, which is instantly perforated, while the sulphide falls to the ground in melted globules, having a yellowish color and metallic lustre. Prepared by the first process, it is partly in crystalline grains, partly in the form of a black powder. It is used for procuring sulphuretted hydrogen gas, which is formed when the protosulphide is dissolved in hydrochloric or sulphuric acid: $\text{Fe S} + \text{H Cl} = \text{Fe Cl} + \text{H S}$.

b. Sesquisulphide of Iron. $\text{Fe}_2 \text{S}_3 = 104.36$.

It is formed by the action of hydrosulphuric acid (sulphuretted hydrogen) on peroxide of iron, at a heat not above 212° , as a

yellowish-gray powder; or by adding perchloride of iron to an excess of sulphide of ammonium, as a black powder, rapidly oxidized by exposure to the air.

c. Bisulphide of Iron. $\text{FeS}_2 = 60.24$.

Syn. Iron Pyrites.—This is a very abundant mineral, of a yellow color and metallic lustre, crystallizing in cubes or octahedrons. When heated in close vessels it loses nearly half its sulphur, which may be collected, magnetic pyrites being left. Iron pyrites is often contaminated with arsenic, which accompanies the sulphur, and is found in the sulphuric acid made from it.

d. Magnetic Pyrites. $\text{Fe}_3\text{S}_7 = 280.7$.

This also occurs in nature, and is attracted by the magnet. It dissolves in acids, yielding sulphuretted hydrogen and a residue of sulphur.

Arfwedson has formed two other sulphides, the tetrasulphide Fe_4S , and the disulphide Fe_2S , which have no particular interest.

Diphosphide of iron is an ingredient in some kinds of iron, and has the bad effect of rendering it cold short, that is brittle at common temperatures.

IRON AND CARBON.

Iron forms with carbon two distinct compounds, the precise composition of which is unknown. These are cast iron and steel.

Cast iron is obtained in the process for extracting iron from its ores. It occurs in two forms, white and gray. Both fuse far more readily than pure iron. White cast iron is very hard and brittle; it contains about 5 per cent. of carbon. Gray cast iron is softer and tougher; it contains between 3 and 4 per cent. of carbon, in part uncombined.

Steel contains from 1.3 to 1.75 per cent. of carbon. It is less fusible than cast iron, and is much harder, more elastic, and more sonorous than pure iron. It is made by cementation: that is, alternate layers of iron and charcoal are placed in a closed chamber and heated to redness for several days, during which time a gradual combination takes place.

28. ZINC. $\text{Zn} = 32.3$.

This metal is found in considerable abundance. It occurs, as sulphide, in zinc blende; and as carbonate of the oxide in calamine. To obtain the metal, the sulphide is roasted in the air till the sulphur is burnt off and the zinc converted into oxide; or, what is preferable, the carbonate is heated till all the carbonic acid and water it contains are expelled, leaving oxide of zinc. The oxide is now mixed with charcoal and the mixture distilled in retorts, or in crucibles, closed at the top, but having a tube open

at both ends fitted into the bottom, and reaching, within, nearly to the cover. The oxide is reduced by the action of the charcoal at a full red-heat, and the metal being volatile, distils over and is condensed in water.

Zinc has a bluish-white color and bright lustre, and tarnishes slowly on exposure to the air. Its Sp. G. is about 7. It is brittle at ordinary temperatures; but, between 250° and 300° , it is both malleable and ductile, and may be rolled or hammered into sheets of considerable thinness. It melts at 773° (Daniell), and at a high red or white-heat sublimes or distils unchanged in close vessels. Heated strongly in air, it takes fire and burns with a beautiful white light, forming oxide of zinc.

ZINC AND OXYGEN.

Protoxide of Zinc. $\text{Zn O} = 40.313$.

The oxide which is formed when zinc is burned in the air is the only compound of these elements. It may also be obtained by heating the carbonate to redness, or by precipitating the sulphate of zinc by a caustic alkali, in which latter case we obtain a bulky gelatinous hydrate of the oxide. Oxide of zinc is a fine white powder, insoluble in water, but very soluble in acids, which it neutralizes, being a very powerful base, of the same class as magnesia.

Solutions of oxide of zinc are recognized by the following characters. Caustic alkalies produce a bulky white precipitate of hydrate, soluble in an excess of the alkali. The alkaline carbonates precipitate a bulky white carbonate of zinc, permanent when carbonate of soda or potash is employed, but soluble in excess of carbonate of ammonia. Sulphuretted hydrogen has no action if the solution be acid; but if it be quite neutral, forms a white precipitate of hydrated sulphide of zinc, which is best formed by sulphide of ammonium. Ferrocyanide of potassium also causes a white precipitate.

Chloride of Zinc. $\text{Zn Cl} = 67.75$.

This compound is formed by the action of chlorine on zinc, or by dissolving zinc in hydrochloric acid, when hydrogen is evolved: $\text{Zn} + \text{H Cl} = \text{Zn Cl} + \text{H}$. The solution is evaporated to dryness, and sublimed in a current of hydrochloric acid gas. It is white, semi-solid, very fusible, volatile at a red-heat, and highly deliquescent. It was formerly called butter of zinc.

Iodide of Zinc. $\text{Zn I} = 158.6$.

When iodine is acted on by excess of zinc under water, an energetic combination takes place, and a colorless solution is obtained which, in evaporation, leaves a deliquescent mass, very

analogous to the chloride, and capable of being sublimed in crystals.

The bromide and fluoride of zinc are little known.

Sulphide of Zinc. $\text{Zn S} = 48.4$.

Sulphide of zinc occurs native, under the name of zinc blende, in dodecahedral crystals, which are sometimes yellow, sometimes red, brown, or black. It may be formed by heating oxide of zinc with sulphur, or sulphate of zinc with charcoal, in a closed crucible: $\text{Zn O, S O}_2 + \text{C}_4 = 4 \text{ C O} + \text{Zn S}$.

29. CADMIUM. $\text{Cd} = 55.8$.

This metal occurs, in the form of carbonate, as an ingredient in various kinds of calamine or carbonate of zinc. It is also found in the form of sulphide, as the rare mineral greenockite, and to the extent of 5 per cent. in some kinds of sulphide of zinc. The metal is, in all its relations, very analogous to zinc, and is almost invariably found associated with it.

When an ore of zinc, containing cadmium, is treated as above described, to obtain the zinc, the first vapors that distil over, which are known as the brown blaze, contain the cadmium, and are separately collected. To purify it from zinc, it is dissolved in an acid, and the solution acted on by a piece of zinc in a platinum vessel. The cadmium is reduced and adheres to the platinum, the zinc being dissolved in its place. When well washed, the cadmium may be dissolved off by nitric acid. Or the acid solution of both metals may be precipitated by sulphuretted hydrogen, which throws down cadmium and not zinc. The sulphide of cadmium is then dissolved in nitric acid. From this solution alkalies throw down oxide of cadmium, which is reduced exactly like oxide of zinc.

Cadmium is in appearance similar to tin, but is harder and more tenacious. It is both malleable and ductile. Its Sp. G. is 8.6. It melts at about 450° , and boils at a temperature not a great deal higher than the boiling point of mercury. When strongly heated in the air, it burns, forming oxide. Like zinc, it forms only one oxide, chloride, sulphide, &c.

Oxide of Cadmium. $\text{Cd O} = 63.813$.

The oxide is best prepared by heating the carbonate to redness. It is an insoluble orange powder, which is a strong base, neutralizing acids. Its salts are easily recognized by the following tests. Caustic alkalies cause a white, bulky precipitate of hydrated oxide, which dissolves in excess of ammonia. Sulphuretted hydrogen produces an orange precipitate of sulphide of cadmium.

The chloride and iodide of cadmium are white fusible compounds.

The sulphide of cadmium is an orange-yellow powder, soluble in nitric acid, and distinguished from yellow sulphide of arsenic, by being insoluble in caustic potash, and fixed in the fire.

30. TIN. $\text{Sn} = 57.9$.

This important metal occurs in Cornwall and in Saxony, in the form of oxide, from which the metal is obtained by heating with charcoal.

Tin is a white metal, with a very high lustre, which is very little tarnished by exposure to the atmosphere. It is very malleable, yielding leaves (tin foil) not thicker than $\frac{1}{1000}$ of an inch. It is soft, and when bent in the fingers makes a peculiar noise. Its Sp. G. is 7.2. It melts at 442° , and if heated to whiteness in air, it takes fire and burns with a white flame, forming peroxide of tin.

TIN AND OXYGEN.

a. Protoxide of Tin. $\text{Sn O} = 65.913$.

This oxide is prepared by adding an alkaline carbonate to a solution of protochloride of tin, when a bulky white precipitate is formed of hydrated protoxide of tin. This is washed with warm water and dried at a heat not above 196° . The dry hydrate is now heated to redness in a current of carbonic acid gas, and the anhydrous protoxide is left.

Peroxide of tin is a dense black powder, which has so strong an attraction for oxygen, that if touched with a red-hot body, it takes fire and burns into peroxide. It dissolves in acids, forming salts which absorb oxygen with avidity, and reduce the oxides of silver, mercury, and platinum to the metallic state, if added to their solutions. With solutions of gold, salts of protoxide of tin produce a purple precipitate, the purple of Cassius; so that salts of gold and salts of protoxide of tin are mutually tests for each other. Salts of protoxide of tin give, with sulphuretted hydrogen, a black precipitate of protosulphide of tin.

b. Sesquioxide of Tin. $\text{Sn}_2 \text{O}_3 = 129.839$.

When moist hydrated peroxide of iron is mixed with a neutral solution of protochloride of tin, an exchange takes place, and a bulky precipitate of a gray color is formed, which is a hydrate of sesquioxide of tin: $\text{Fe}_2 \text{O}_3 + 2 \text{Sn Cl} = \text{Sn}_2 \text{O}_3 + 2 \text{Fe Cl}$. The sesquioxide is soluble in acids and in ammonia, the latter character distinguishing it from the protoxide. Its solution in hydrochloric acid forms, with chloride of gold, the purple of Cassius; and seems, indeed, better adapted for making it than the protoxide.

c. Peroxide of Tin. $\text{Sn O}_2 = 73.926$.

This oxide exists in two distinct modifications:—1. If made by the action of nitric acid on tin, which is very violent, it appears

as a dense white opaque powder, which is a hydrate, insoluble in water or acids. 2. If prepared by adding potash to perchloride of tin, it forms a very bulky hydrate, readily soluble in acids and also in alkalies. It seems rather to possess the characters of a weak acid than of a base. It is recognized in its solution in acids, by forming with alkalies a bulky white hydrate, readily dissolved by excess of potash or soda, and by yielding, with sulphuretted hydrogen, a dirty yellow precipitate of bisulphide of tin. When melted with glass, peroxide of tin renders it opaque, forming a white enamel.

TIN AND CHLORINE.

a. Protochloride of Tin. $\text{Sn Cl} = 93.37$.

This chloride is formed when chlorine gas is passed over metallic tin moderately heated, when hydrogen is given off. When dry it is a gray solid, fusible below redness. Tin dissolves in hydrochloric acid, and the concentrated solution deposits acicular crystals, which are a hydrated chloride: $\text{Sn Cl} + 3 \text{H O}$. When heated, they give off water and hydrochloric acid, while protoxide is left: $\text{Sn Cl} + 3 \text{H O} = \text{Sn O} + \text{H Cl} + 2 \text{H O}$. The addition of a large quantity of water decomposes these crystals, causing the formation of an insoluble white powder, which is a compound of oxide and chloride with water. The solution of protochloride of tin, made by digesting an excess of tin in hydrochloric acid as long as hydrogen is given off, is much used as a deoxidizing agent. It is apparently resolved into bichloride and metal, $2 \text{Sn Cl} = \text{Sn Cl}_2 + \text{Sn}$; and the latter, probably, is the true agent in deoxidizing. It is also used for making the purple of Cassius.

b. Perchloride of Tin. $\text{Sn Cl}_2 = 128.74$.

When protochloride of tin is heated in excess of chlorine gas, or when 8 parts of tin powder are distilled with 24 of bichloride of mercury, a volatile fuming liquid is obtained, formerly known as the fuming liquor of Libavius, which is bichloride of tin. It is obtained in solution by dissolving tin in nitro-hydrochloric acid of moderate strength, adding small portions of tin at a time; also by forming a solution of protochloride, and passing chlorine through it, or heating it gently with a little nitric acid. It is much used in dyeing as a mordant.

The protoiodide of tin is a brownish-red fusible solid, dissolving in water; the periodide forms silky yellow crystals.

TIN AND SULPHUR.

a. Protosulphide of Tin. $\text{Sn S} = 74$.

This compound is formed by pouring melted tin on its own weight of sulphur, and stirring well. The mass is then powdered,

mixed with more sulphur, and thrown by degrees into a red-hot crucible, by which means the whole of the tin is sulphurized. It forms a bluish-black brittle solid, having metallic lustre. It is also formed when sulphuretted hydrogen acts on solutions of protoxide or protochloride of tin.

b. Persulphide of Tin. $\text{Sn S}_2 = 90.1$.

This sulphide, formerly called *aurum musivum*, is prepared by heating to low redness, in a retort, a mixture of 2 parts peroxide of tin, 2 of sulphur, and 1 of sal ammoniac. The sulphide is left in the form of golden-yellow scales, having a metallic lustre. It is soluble in potash. It is also formed as a dirty-yellow bulky hydrate by the action of sulphuretted hydrogen on solutions of peroxide or perchloride of tin.

31. COBALT. $\text{Co} = 29.5$.

This metal occurs pretty abundantly, generally combined with arsenic, and associated with nickel and iron. A trace of it is always found in meteoric iron. To obtain the metal from the arseniuride, the ore, finely powdered, is gradually added to 3 parts of bisulphate of potash, melted in a moderate heat, and gradually increasing the fire, till no more white fumes appear. The mass, when cold, is powdered and boiled with water as long as anything is dissolved. The solution is free from arsenic, and contains sulphate of protoxide of cobalt. It is precipitated by carbonate of soda, and the washed precipitate acted on by oxalic acid, which forms an insoluble pink powder of oxalate of protoxide of cobalt. Should iron be present, it forms a soluble compound with the oxalic acid, provided it has been brought into the state of peroxide by boiling the solution with a little nitric acid before precipitating with carbonate of soda. The only impurity now likely to be present is nickel, and to separate this, the oxalate is dissolved in an excess of ammonia, and the solution exposed to the air in a deep glass vessel. As the ammonia evaporates, the nickel is deposited (if present) in the form of a pale-green insoluble double oxalate of nickel and ammonia, while the cobalt remains dissolved, forming a port-wine-colored solution. This being digested with excess of potash, yields a dark brown precipitate of pure peroxide of cobalt. This is again dissolved in hydrochloric acid, the solution precipitated by caustic potash or carbonate of soda, and the precipitate converted into oxalate, which is now quite pure; and the oxalate being heated to whiteness in a closed crucible, with a small aperture for escape of gas, leaves a button of pure metallic cobalt. The oxalate of cobalt, $\text{Co O, C}_2 \text{ O}_3$, is resolved by the heat into carbonic acid and metal: $\text{Co O, C}_2 \text{ O}_3 = \text{Co} + 2 \text{ C O}_2$.

Cobalt is a metal of a reddish-gray color, rather brittle and very infusible. Its Sp. G. is 7.8. It is attracted by the magnet. At a red-heat it decomposes water, hydrogen being disengaged.

COBALT AND OXYGEN.

a. Protoxide of Cobalt. $\text{Co O} = 37.518$.

Obtained by calcining carbonate of cobalt in close vessels, as an ash-gray powder. It is a strong base, and forms, with acids, salts which are either pink or blue. Zaffre and smalt, which are so much used for painting blue on porcelain, and by the paper-makers to correct the yellow tinge of their paper, are silicates of this oxide. The solutions of its salts are precipitated by caustic alkalies, which form a blue hydrate, gradually changing to green, soluble in excess of ammonia. Carbonates produce a lilac-colored precipitate of carbonate of cobalt. Sulphuretted hydrogen produces no change: the sulphide of ammonium produces a black sulphide.

When this oxide, or the peroxide of cobalt, are heated in the air, they both yield a black oxide, which corresponds to the red oxides of manganese, its formula being $\text{Co}_2\text{O}_4 = \text{Co O} + \text{Co}_2\text{O}_3$. The green hydrate, formed when hydrate of the protoxide is exposed to the air, is a hydrate of this oxide.

b. Peroxide of Cobalt. $\text{Co}_2\text{O}_3 = 83.039$.

Syn. Sesquioxide of Cobalt.—When bleaching liquor (hypochlorite of lime) is added to solutions of protoxide of cobalt, or when chlorine is passed through hydrated protoxide suspended in water, a black powder is formed, which is hydrated peroxide. 3 eqs. protoxide, and 1 eq. chlorine, yield 1 eq. protochloride and 1 eq. peroxide: $3 \text{ Co} + \text{Cl} = \text{Co}_2\text{O}_3 + \text{Co Cl}$.

Peroxide of cobalt is, like peroxide of manganese, an indifferent or neutral oxide, for it does not combine with acids; and when dissolved in hydrochloric acid, it forms protochloride, chlorine being disengaged.

Chloride of Cobalt. $\text{Co Cl} = 64.95$.

Obtained by dissolving cobalt, or any of its oxides, in hydrochloric acid. The solution is pink, and on evaporation yields beautiful red crystals of hydrated chloride, or possibly hydrochlorate of the oxide. When dried by heat, the chloride is of a deep blue, but is instantly rendered pink by the contact of water. The crystals are either Co Cl , H O , or Co O , H Cl . When traces are made on paper with a dilute solution of chloride of cobalt, they are invisible when dry; but, when warmed, assume a decided blue color, which disappears again on cooling, as they again absorb moisture from the air. This is the most beautiful of the sympathetic inks. If iron or nickel be present, the traces appear green instead of blue.

The sulphides of cobalt are not of much interest. The proto-sulphide, Co S , is formed when sulphide of ammonium acts on

salts of protoxide of cobalt as a black precipitate. According to Wöhler, sulphide of cobalt is easily obtained by fusing the arsenide of cobalt with 3 parts of pearlash and 3 parts of sulphur. The arsenic forms a soluble compound, and this is removed by water, leaving sulphide of cobalt as a black powder. This may be dissolved in nitric acid, and the cobalt purified from iron and nickel, as above described. This process for extracting cobalt from its ores would seem to be the best of all.

The compounds of cobalt, when fused with glass, give to it a beautiful blue color, and their use in painting the blue patterns on china is well known. The finest cobalt-blue for painting is made by heating a mixture of 15 parts of alumina with 2 of phosphate of cobalt to redness.

32. NICKEL. $Ni = 29.5$.

This metal is rather rare; it occurs, like cobalt, chiefly in combination with arsenic, and associated with iron and cobalt. A very good method of extracting it from the arsenide, or speiss, as it is called, is that of Wöhler, which is, to fuse the speiss with 3 parts of pearlash and 3 parts of sulphur. The arsenic forms, with the sulphur and potash, a soluble compound, and the nickel forms with the sulphur an insoluble sulphide. This is well washed with water, and dissolved in nitric acid; and the solution, after any lead, copper, or bismuth that may be present, have been precipitated by a current of sulphuretted hydrogen, is precipitated by caustic or carbonated potash or soda. The washed precipitate is now acted on by an excess of oxalic acid, which forms, with the peroxide of iron that is generally present, a soluble, and with the oxide of nickel an insoluble oxalate, which of course includes any cobalt that the ore may have contained. The oxalate is now dissolved in an excess of ammonia, and the solution exposed to the air. As the ammonia escapes, the nickel is deposited as an insoluble double oxalate, while the cobalt remains dissolved as a soluble double oxalate, of the metallic oxide with ammonia. The nickel salt, being ignited, leaves an oxide, which may be reduced by heating with charcoal, or dissolved in acid, and again converted into oxalate, which this time is free from cobalt, and appears as a pale apple-green powder. The oxalate of nickel, being well washed, dried, and ignited in a closed crucible, with an aperture for the escape of gas, leaves metallic nickel, which, if the heat be very intense, is fused into a button.

Wöhler gives another process, which is said to be preferable to the above. It consists in projecting the finely powdered ore along with 2 parts of nitre and one of carbonate of potash, by degrees, into a red-hot crucible, and finally raising the heat for a good while. The arsenic is oxidized, yielding arsenic acid, which unites

with the potash, while the nickel is also oxidized, and forms oxide of nickel, which is left undissolved when the mass is lixiviated with water. This oxide is pure, except from cobalt and iron, which must be separated as above. When these metals are not present, the oxide may be at once reduced by heating with charcoal, and yields pure nickel.

Nickel is nearly silver-white, but has a tinge of gray. It has a high lustre, is hard, and malleable. Its Sp. G. is 8.9. It is very infusible, and decidedly magnetic. It decomposes water at a red-heat. Magnetic needles may be made of it, which do not rust. It is now much used in the manufacture of German silver or argentan, which is an alloy of copper, zinc, and nickel. The better qualities contain more nickel than the inferior kinds.

NICKEL AND OXYGEN.

Protoxide of Nickel. $\text{Ni O} = 37.513$.

Its preparation is given above, in Wöhler's second process for metallic nickel. It is a greenish-gray powder, which is a base, and forms, with acid, salts which are all green of different shades. Solutions of these salts give pale apple-green precipitates of hydrate and carbonate, with caustic and carbonated potash and soda. Ammonia causes a slight precipitate, which is instantly redissolved by an excess, forming a violet-blue solution. Salts of nickel are not precipitated, in acid solutions, by sulphuretted hydrogen, but sulphide of ammonium causes a black precipitate of sulphide of nickel.

b. Peroxide of Nickel. $\text{Ni}_2\text{O}_3 = 83.039$.

SYN. Sesquioxide of Nickel—May be formed by passing chlorine through water in which the hydrated protoxide is suspended. It is an indifferent oxide or superoxide, analogous to sesquioxide of cobalt. It is a black powder.

Chloride of Nickel. $\text{Ni Cl} = 64.95$.

Analogous to chloride of cobalt. Its solution is emerald-green, and yields crystals of the same color; but when entirely deprived of water, it is yellow. At a low red-heat it sublimes and condenses in brilliant gold-yellow scales.

Protosulphide of Nickel. $\text{Ni S} = 45.6$.

Analogous to protosulphide of cobalt, and formed in the same way. Sulphur and nickel unite when heated together, with disengagement of heat and light, forming a grayish-yellow metallic mass. The precipitated sulphide is black. Sulphide of nickel is found native in fine crystals of a pale brass-color, as the Haarkies of the Germans.

ORDER 2. — METALS WHICH DO NOT DECOMPOSE WATER AT ANY TEMPERATURE, AND THE OXIDES OF WHICH ARE NOT REDUCED TO THE METALLIC STATE BY THE SOLE ACTION OF HEAT.

33. ARSENIC. $As = 75.4$.

This metal is occasionally found native, but it is chiefly met with in combination with cobalt, nickel, and iron. When the arsenides of these metals are heated to redness in a current of air, a great part of the arsenic, being volatile, rises in vapor, and is deposited in the cold part of the chimney in the form of white oxide of arsenic or arsenious acid, the well-known white arsenic of commerce. This substance is mixed with charcoal or black flux (a mixture of charcoal with carbonate of potash), and the mixture introduced into a medicine phial, filling it about one-third. The phial is then placed in sand, the sand reaching as high as the mixture, and gradually heated to low redness. The metal sublimes and condenses in the upper part of the phial, which, when cold, may be cut off.

Arsenic is a very brittle metal, of a whitish-gray color, and very high lustre. Its Sp. G. is 5.80. When heated to 356° , it sublimes without previously melting, its melting point being higher than its boiling point under the usual pressure. Its vapor has a strong alliaceous smell, a property which is characteristic of arsenic, no other metal possessing it. It sometimes rapidly tarnishes on exposure to the air, becoming nearly black; and when sublimed in a current of air it is oxidized, being converted into arsenious acid. The rapid tarnishing of arsenic is probably owing to the presence of a little potassium, derived from black flux: for the native metal, when sublimed, does not tarnish.

ARSENIO AND OXYGEN.

a. Arsenious Acid. $AsO_2 = 99.439$.

The formation of this substance, when arsenic is sublimed in a current of air has been mentioned. It occurs, when newly sublimed, as a hard brittle glass; which, when kept, slowly becomes opaque and crystalline, the change often taking years to reach the centre of a small lump of the glass. The Sp. G. of arsenic acid is 3.7. At 380° it sublimes, yielding inodorous vapors, which condense in octohedral crystals, when the sublimation is slowly conducted in a glass tube.

It has little taste, which renders it the more dangerous as a poison; as, when taken by mistake, there is no warning, as in the case of many other poisons. It is sparingly soluble in water, but the crystalline variety is more soluble than the glassy; 100 parts of hot water dissolving 11.5 of the former, and only 9.7 of the latter.

Arsenious acid, whether in the solid form or in that of solution, is a most virulent poison, and is, unfortunately, so accessible as

to be often used for criminal purposes. Its detection, therefore, is a matter of the utmost importance; and innumerable tests, more or less effectual, have been proposed. These, however, may with advantage be reduced to a very small number; which again are best divided into—1. Those tests which apply to pure arsenious acid, or its salts; and, 2. Those which apply to mixtures, such as are likely to occur in medico-legal investigations.

1. Pure arsenious acid is easily recognized, as a heavy white powder, volatile, without smell, sparingly soluble in water, and, when heated with charcoal, black flux, formiate of soda, or cyanide of potassium, yielding a volatile crust of metallic arsenic, the vapors of which have the odor of garlic.

The solution gives, with lime-water in excess, an insoluble white precipitate of arsenite of lime; with ammoniaco-nitrate of silver, a yellow precipitate of arsenite of silver; with ammoniaco-sulphate of copper, a grass-green precipitate of arsenite of copper; and with sulphuretted hydrogen, acetic or hydrochloric acid being first added to the solution, an orange-yellow precipitate of tersulphide of arsenic. When to the solution of arsenious acid, or of any of its salts, sulphuric acid is added, and a portion of pure zinc introduced into the acid liquid, the hydrogen disengaged by the action of the zinc on the acid, is found to be mixed with a portion of arseniuretted hydrogen gas, the presence of which gives it an alliaceous smell, and causes it to burn with a pale blue flame. If a piece of cold glass or porcelain be held in contact with this flame, a black stain or crust of metallic arsenic is deposited on it, and this crust may be easily recognized by its volatility, and the other characters of arsenic.—(*Marsh.*) If the hydrogen gas, containing arseniuretted hydrogen, instead of being burned at the end of the tube, be slowly passed through a long narrow tube of hard glass, part of which is heated to redness, the arseniuretted hydrogen is decomposed at the red-hot part of the tube, and the arsenic deposited as a bright metallic crust, a little beyond the hot part.

2. When, however, arsenious acid occurs in mixtures containing much organic matter, such as, for example, are found in the stomach or intestines of those poisoned with arsenic, or in the matters vomited before death, a method must be adopted which removes all organic matters, and permits the operator to test for arsenic with security. The following method, lately proposed by Fresenius and Von Babo, is perhaps the best:

a. Two-thirds of the suspected mixture, or contents of the stomach, all solid parts being cut small, are introduced into a large porcelain capsule (the remainder being kept in case of accidents), and mixed with a moderate quantity of pure hydrochloric acid, and as much water as gives to the whole the consistence of a thin gruel, which is heated in the vapor bath, and chlorate of

potash added at intervals of five minutes in portions of 20 or 30 grains to the hot liquid, until the whole has become clear yellow, perfectly homogeneous and fluid. At this point about 2 drachms more of chlorate are added, and the vessel removed from the vapor bath. When quite cold it is strained through linen, or filtered, and the residue on the filter well washed with hot water. The whole liquid is now evaporated on the water bath to the bulk of about one pound, and the acid residue, which is generally now brownish in color, mixed with as much of a saturated solution of sulphurous acid as gives a permanent smell of that acid. It is then heated until the excess of sulphurous acid is entirely expelled.

In this first stage of the process the arsenious acid is dissolved, the organic matter destroyed in a great measure by the chlorate of potash and hydrochloric acid, and the arsenic, which had thereby been converted into *arsenic* acid, reduced by the sulphurous acid to the state of arsenious acid. The destruction of the organic matter renders the filtration rapid and easy.

b. The acid liquid is now exposed for twelve hours to a current of sulphuretted hydrogen gas, the gas tube is washed with a little ammonia, which is added to the mass of liquid, and the whole allowed to stand, covered with paper, in a warm place, until the smell of sulphuretted hydrogen disappears. The precipitate which has formed, and which contains sulphide of arsenic along with some organic matter, and possibly other metallic sulphides, is collected on a small filter and well washed.

Here the arsenious acid is converted into tersulphide of arsenic, by the sulphuretted hydrogen: $\text{As O}_3 + 3 \text{HS} = \text{As S}_3 + 3 \text{H O}$.

c. The filter with the precipitate is dried in the vapor bath, moistened with fuming nitric acid, and the mass dried up in the water bath. Pure oil of vitriol is now added, so as to moisten the dry mass uniformly, the mixture is heated for two or three hours in the vapor bath, and, finally, dried on the sand bath at a heat not exceeding 290° , till the charred mass assumes a brittle consistence. It is then heated in the vapor bath with from ten to twenty parts of distilled water, filtered, and the charcoal perfectly washed with hot distilled water. The whole filtered liquid is now mixed with hydrochloric acid and again precipitated by sulphuretted hydrogen, exactly as before. The precipitate is collected on a very small filter, well washed, and dissolved on the filter by ammonia, with which the filter is well washed. The ammoniacal solution of sulphide of arsenic is evaporated to dryness in a small porcelain vessel, and the residue may be weighed if required.

In this stage the remaining organic matter is entirely destroyed, and the arsenic obtained in the form of pure tersulphide.

d. For obtaining the metallic arsenic from this sulphide, or reducing the sulphide, which is the decisive proof, the following

apparatus is employed (see cut, fig. 50). A is a well-sized flask, for generating carbonic acid gas, half filled with water and frag-

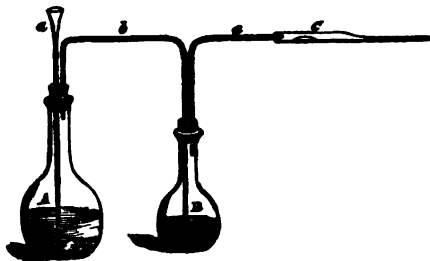


FIG. 50.

ments of marble. Through one aperture in the cork passes the funnel tube *a*, reaching nearly to the bottom; through the other passes a tube *b*, which conducts the gas into the smaller flask B, in which it is washed and dried by passing through oil of vitriol. The tube *c* carries the gas into the reduction tube C, which is represented in fig 51, a little less than half the real size.

When the whole is fitted and arranged, a portion of the dried sulphide (reserving part for other experiments, or in case of accident), is mixed in a warm agate mortar with about twelve parts of a mixture of three parts of dried carbonate of soda, and one part of cyanide of potassium. The mixed powder is carefully introduced, by means of a half cylinder of card, into the reduction tube, which is then turned on its axis, so as to allow the powder to lie on the part *a f*, fig. 51, of the reduction tube. The card is then removed. The reduction tube is now attached to the gas apparatus, and hydrochloric acid poured into the flask A, through the funnel, so as to cause a disengagement of carbonic acid gas, which fills the whole apparatus. The tube is then gently warmed through its whole length until all traces of moisture have disappeared, and when the current of gas has become so slow that the bubbles follow each other at an interval of about a second, the part *b* of the reduction tube (fig. 51), is heated to

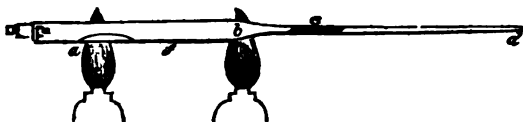


FIG. 51.

redness by a spirit lamp. This being done, the powder is now heated by another spirit lamp, from *a* toward *f*, gradually, till all the arsenic is expelled.

The reduced arsenic is deposited as a bright metallic ring at *c*, fig. 51, a mere trace only escaping at *d*. The second lamp is then brought toward *b*, in order to collect any trace of arsenic in the wide part of the tube, and the point *d* being closed by melting it, and the tube detached, the arsenic is driven into as small a space as possible, by heating from *d* towards *c*. The tube is now cut across at *f*, corked, sealed, and preserved as evidence. If the above process be followed exactly, the result is a ring of astonishing purity and brilliancy. The use of the carbonic acid is to prevent oxidation by the air, which as well as moisture, if admitted, would very much interfere with the result.

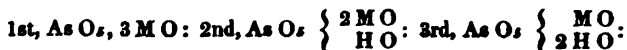
This is not the place to notice the very numerous methods which have been proposed for the detection of arsenic in mixed fluids. It is enough to say that none of them is preferable to the above, if indeed any are equal to it, in point of facility, delicacy, and security. The process of Marsh, by hydrogen gas, as above described, is indeed very delicate, but it is rendered less secure by the fact, that antimony, if present, gives somewhat similar appearances. In the method of Fresenius and Von Babo, antimony, if present, remains in the residue of the powder heated in the reduction tube, where it may be found, chiefly in the metallic state, and partly in a soluble combination.

The only known antidote to arsenious acid is the hydrated peroxide of iron, the ferrugo of the Edin. Pharmacopœa, which should be given in the moist state mixed with water. When made for this purpose, the precipitated oxide should never be dried, but kept under water; as when once dried, it is far less efficacious. It acts by combining with the arsenious acid, forming a compound which is quite insoluble and inert, and is a basic arsenite of sesquioxide of iron, $\text{Fe}_2\text{O}_3, \text{AsO}_3$.

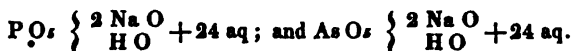
b. Arsenic Acid. $\text{AsO}_5 = 115.485$

This acid is found in nature combined with oxides of calcium, lead, copper, iron, cobalt, and nickel. It is easily prepared by dissolving arsenious acid in nitric acid, with a little hydrochloric acid, and evaporating to a syrup, which is heated gently till all nitric acid is expelled. The residue is hydrated arsenic acid, $\text{AsO}_5, 3\text{H}_2\text{O}$, or AsO_5, H_2 . It is a very acid, poisonous substance, remarkable chiefly for its analogy with common or tribasic phosphoric acid. This analogy is so great, that for every tribasic phosphate, there is a corresponding arseniate: and this is not all, for the external properties of these salts are so exactly similar, that, except by analysis or characteristic tests, we cannot tell whether arsenic, or phosphoric acid, be present. Not only are the native phosphates of copper, lead and iron, exactly like the arseniates in color, crystalline form, and constitution, but the phosphates are seldom found unmixed with arseniates.

The complete isomorphism of arsenic and tribasic phosphoric acids in their salts, is one of the finest examples of isomorphism depending on similarity of constitution. Like the tribasic phosphates, the arseniates occur in 3 forms.



and the crystalline form in all yet examined is the same as that of the corresponding phosphates. Thus the arseniate of soda, with 2 eqs. soda, and 1 eq. water, is not to be distinguished, in external aspects, from the common phosphate of soda. The formulæ are:



It is highly probable that phosphorus and arsenic are themselves entirely isomorphous as elements; and in one particular they are alike, besides the analogy of their compounds; namely, the alliaceous odor of their vapor.

The salts of arsenic acid give with nitrate of silver a brick-red precipitate of tribasic arseniate of silver: $AsO_3, 3AgO$: and with hydrochloric acid and sulphuretted hydrogen, a pale yellow precipitate of persulphide of arsenic, AsS_3 .

No modifications of arsenic acid, analogous to bibasic and monobasic phosphoric acids, are yet known.

ARSENIC AND CHLORINE.

Terchloride of Arsenic. $AsCl_3 = 18.166$.

Prepared by distilling 6 parts of bichloride of mercury with 1 part of metallic arsenic: $3HgCl_2 + As = 3HgCl + AsCl_3$. It is a colorless, volatile, fuming liquid, which is resolved, by the action of water, into hydrochloric and arsenious acids: $AsCl_3 + 3HO = AsO_3 + 3HCl$.

ARSENIC AND IODINE.

Periodide of Arsenic. $AsI_3 = 706.9$.

When arsenic and iodine are gently heated together, they combine, and form a red solid compound, which by the action of water yields arsenic and hydriodic acids: $As_2I_3 + 5HO = As_2O_3 + 5HI$.

ARSENIC AND BROMINE.

Terbromide of Arsenic. $AsBr_3 = 313.6$.

Arsenic and bromine when brought in contact, instantly combine, with vivid combustion. The compound is a solid, melting at about 70° , and boiling at 430° . It is transparent, and slightly

yellow, and occasionally forms long prismatic crystals. With water it yields arsenious and hydrobromic acids.

ARSENIC AND HYDROGEN.

When an alloy of arsenic and potassium is made to act on water, there is formed a brown solid body, which is said to be a protohyduret of arsenic: $\text{As H} = 38.7$.

When arsenic is melted with an equal weight of zinc, an alloy is formed, which, when acted on by strong hydrochloric acid, yields a gas which is colorless, has a strong garlic odor, burns with a blue flame, and is distinguished from all other gases by being totally absorbed, when pure, by a saturated solution of sulphate of copper. It is frightfully poisonous when respired, even in very small proportion, along with common air; and the incautious experimenting with it has proved fatal to more than one chemist. It acts on many metallic solutions, forming insoluble arsenides. When heated to redness it is decomposed, arsenic being deposited, and hydrogen, equal to one and a half times the bulk of the gas, being separated. This gas is formed when hydrogen is generated in a liquid containing arsenious acid dissolved, and mixes with the hydrogen; and when the mixture is heated red-hot in passing through a tube, or burned, a cold plate being held in the flame, arsenic is deposited. This is the principle on which Marsh's process for detecting arsenious acid is founded.

ARSENIC AND SULPHUR.

a. Protosulphide of Arsenic. $\text{As S} = 53.8$.

Formed by melting arsenious acid with half its weight of sulphur. It is a red translucent solid, which may be sublimed in close vessels. It occurs in the mineral kingdom as realgar.

b. Tersulphide of Arsenic. $\text{As S}_3 = 123.7$.

Prepared by melting together equal weights of arsenious acid and sulphur, or by passing a current of sulphuretted hydrogen through a solution of arsenious acid. It has an orange-yellow color, is fusible, and may be sublimed in close vessels. It is very soluble in caustic alkalies, yielding colorless solutions. It occurs in the mineral kingdom as auripigmentum, or orpiment, and is an ingredient in king's-yellow. It may be used for dyeing silk, woollens, or cottons yellow, by soaking them in a solution of orpiment in ammonia, and then suspending them in a warm chamber. The ammonia evaporates, and the orpiment remains firmly fixed in the cloth. This sulphide is the form in which arsenic is best separated from mixed liquids in medico-legal investigations.

c. Persulphide of Arsenic. $\text{As}_2\text{S}_2 = 156$.

Formed by the action of sulphuretted hydrogen on arsenic acid, or on arseniates acidulated by acetic acid. It is of a paler yellow than orpiment, is soluble in alcalies, fusible, and in close vessels volatile without change.

34. CHROMIUM. $\text{Cr} = 28$.

Occurs in nature, in union with oxygen, as chromic acid in chromate of lead, and as oxide of chromium in chrome iron ore, from which latter all the compounds of chromium are obtained. The metal is very infusible, and has probably never been completely melted. It is obtained with difficulty in hard coherent masses of an iron-gray color, by heating the oxide to the highest temperature of a wind furnace for some hours, in a crucible lined with charcoal. In this state it is hardly at all acted on by the strongest acids, but is oxidized by fusion with nitre, yielding chromic acid.

CHROMIUM AND OXYGEN.

a. Sesquioxide of Chromium. $\text{Cr}_2\text{O}_3 = 80.039$.

This oxide may be obtained by heating to redness the bichromate of potash, $\text{K}_2\text{O}, 2\text{CrO}_5$; when neutral chromate, $\text{K}_2\text{O}, \text{CrO}_3$, is formed, sesquioxide is produced, Cr_2O_3 , and oxygen is disengaged, $2(\text{K}_2\text{O}, 2\text{CrO}_5) = 2(\text{K}_2\text{O}, \text{CrO}_3) + \text{Cr}_2\text{O}_3 + \text{O}_2$. The neutral chromate is dissolved out by water and the oxide is obtained as a crystalline green powder; or it may be prepared by heating a mixture of bichromate with carbonate of soda and sal ammoniac to redness. The hydrate is obtained by heating solution of bichromate with hydrochloric acid and alcohol or sugar, till the liquid becomes of a pure green, and adding ammonia, which precipitates the hydrate, as a pale bluish-green bulky powder.

Sesquioxide of chromium is isomorphous with sesquioxide of iron and alumina, and has been obtained in crystals exactly resembling specular iron ore. It is a weak base, and may be substituted for alumina or peroxide of iron in their salts, without altering the form. All its salts are green or blue, and most of them are red by transmitted candle-light. Oxide of chromium appears to exist in its salts in two modifications, in one of which the solutions are pure green, in the other of a mixed tint of red and green. The oxide may be used for painting a beautiful green on china, and for giving glass a green color, or as a paint, being very permanent.

b. Chromic Acid. $\text{CrO}_3 = 52.039$.

Prepared by adding 1 vol. of a cold saturated solution of bichromate of potash to $1\frac{1}{2}$ vol. of pure oil of vitriol, and allowing

the mixture to cool in a covered capsule, or in a flask, when it deposits beautiful deep-red needles of chromic acid. The liquid being drained off, these are laid on a porous brick to dry, covered with a bell-jar. They must be preserved in very tightly-stoppered bottles, as they are highly deliquescent.

Chromic acid is a strong acid, isomorphous with sulphuric, selenic, and manganic acids. Its salts are yellow, orange, or red, and distinguished by the beauty and permanence of their colors. The acid itself is a powerful oxidizing agent, yielding half its oxygen readily to oxidizable bodies, and being reduced to sesquioxide: $2 \text{CrO}_3 = \text{Cr}_2\text{O}_3 + \text{O}_2$. Thus it instantly sets fire to alcohol when thrown into that fluid; and a mixture of bichromate of potash and sulphuric acid is much used as a means of oxidizing organic products, and yielding new compounds. Chromic acid and oxide of chromium are both easily recognized in solutions by their color, and the acid especially by its ready convertibility into the oxide by deoxidizing agents.

According to Barreswill there exists a perchromic acid, Cr_2O_7 , corresponding to permanganic acid. It is formed by the action of peroxide of hydrogen on chromic acid, and has a fine deep-blue color. It is almost immediately resolved, however, into chromic acid and oxygen.

CHROMIUM AND CHLORINE.

a. Sesquichloride of Chromium. $\text{Cr}_2\text{Cl}_3 = 362.96$.

Prepared by passing chlorine over a mixture of sesquioxide of chromium and charcoal heated to redness. It collects in the cold part of the tube as a crystalline peach-blossom-colored sublimate, which dissolves in water, forming a green solution, which probably contains hydrochloric acid and sesquioxide: $\text{Cr}_2\text{Cl}_3 + 3 \text{H}_2\text{O} = \text{Cr}_2\text{O}_3 + 3 \text{HCl}$. The sesquichloride exists in another modification as a pink insoluble powder.

b. Oxychloride of Chromium. $\text{Cr} \left\{ \begin{smallmatrix} \text{O}_2 \\ \text{Cl} \end{smallmatrix} \right.$; or $\text{CrCl}_3 + 2 \text{CrO}_3$.

This compound is formed when neutral chromate of potash, common salt, and oil of vitriol are heated together: $(\text{K O}, \text{Cr O}_3) + \text{Na Cl} + 2 \text{SO}_3 = (\text{K O}, \text{SO}_3) + (\text{Na O}, \text{SO}_3) + \text{Cr O}_2 \text{Cl}$; or $3 (\text{K O}, \text{Cr O}_3) + 3 \text{Na Cl} + 6 \text{SO}_3 = 3 (\text{K O}, \text{SO}_3) + 3 (\text{Na O}, \text{SO}_3) + \text{Cr Cl}_3 + 2 \text{Cr O}_3$. It distils over as a deep-red fuming liquid, which decomposes water, producing hydrochloric and chromic acids. It sets fire to phosphorus and many other combustible bodies. When its vapor is passed through a red-hot tube it is resolved into oxygen, chlorine, and sesquioxide of chromium, $2 \text{Cr O}_2 \text{Cl} = \text{Cr}_2\text{O}_3 + \text{O} + \text{Cl}_2$; or $2 (\text{Cr Cl}_3 + 2 \text{Cr O}_3) = 3 \text{Cr}_2\text{O}_3 + \text{O}_2 + \text{Cl}_2$. Its constitution is uncertain, as according to the two formulæ above given, it may be viewed either

as chromic acid, in which 1 eq. of oxygen is replaced by chlorine, or as a compound of 1 eq. tetrachloride of chromium, and 2 eqs. chromic acid.

c. Perfluoride of Chromium.

When a mixture of chromate of lead, fluoride of calcium, and oil of vitriol, or, better, fuming sulphuric acid, is distilled in a silver retort, there is disengaged a red gas, which, in contact with the moisture of the air, produces hydrofluoric and chromic acids. Its precise composition is unknown. It was formerly considered a tetrafluoride; but it appears that this is not the case, and that it is more probably a pentafluoride, Cr F_5 . Possibly it may be, like the preceding compound, an oxyfluoride.

35. VANADIUM. $\text{V} = 68.5$.

This very rare metal is found in small quantity in the slag of the iron furnaces where the iron ore of Taberg, in Sweden, is smelted, also in the lead mines of Scotland, as vanadate of lead, a mineral which likewise occurs in Mexico. The metal is brittle, very infusible, and nearly silver white. In its chemical relations it is somewhat analogous to chromium; and, like it, forms colored compounds. It is not oxidized either by air or water, and the only acid that dissolves it is aqua regia.

a. Protoxide of Vanadium. $\text{VO} = 76.513$.

A black powder, which being heated burns into deutoxide.

b. Deutoxide of Vanadium. $\text{VO}_2 = 84.526$.

This oxide, when anhydrous, is black, but forms blue salts; these are apt to become first green and then red, from the formation of vanadic acid.

c. Vanadic Acid. $\text{VO}_3 = 92.539$.

Is obtained from vanadate of lead by dissolving it in nitric acid, and precipitating lead and arsenic by sulphuretted hydrogen, which reduces the acid to deutoxide. The blue solution is evaporated, during which vanadic acid is reproduced, and the dry mass is digested in ammonia, which dissolves the acid. Into this solution a lump of sal ammoniac is introduced, and, as this dissolves, the vanadate of ammonia separates, being insoluble in a saturated solution of sal ammoniac. When this salt is heated to a point below red-heat in an open vessel, the ammonia is expelled, and vanadic acid left, which melts below a red-heat, and on cooling forms beautiful red crystals. With bases it forms salts which are either red or yellow, according as they are acid or neutral salts. It is singular that the neutral vanadates of the alkalies may occur both yellow and colorless without any known difference in compo-

sition. Vanadic acid unites with deutoxide of vanadium, forming compounds which are purple, green, yellow, or orange, according as the acid or oxide predominates. Vanadic acid is distinguished from chromic acid by yielding a blue solution, when deoxidized, instead of a green one.

With chlorine, vanadium forms a bichloride, $V Cl_2$, and a terchloride, $V Cl_3$. The latter is formed by passing chlorine over a mixture of protoxide of vanadium and charcoal, heated to low redness, when the terchloride distils over as a yellow fuming liquid, which decomposes water, producing hydrochloric and vanadic acids. When this chloride is exposed to a current of ammonia, a white compound is formed, and if this be heated in a continued current of ammonia, metallic vanadium is formed, and adheres to the tube.

36. MOLYBDENUM. $Mo = 47.7$.

This metal occurs in nature, combined with sulphur, forming a lead-colored metallic mineral in broad plates or leaves, called molybdena, or sulphide of molybdenum. It is found more sparingly as molybdic acid combined with lead. The metal may be obtained by passing hydrogen gas over molybdic acid, heated to whiteness in a porcelain tube. It is a brittle white metal, almost quite infusible. It forms three oxides.

MOLYBDENUM AND OXYGEN.

a. Protoxide of Molybdenum. $Mo O = 55.713$.

A black powder, which, when heated in the air, takes fire and forms deutoxide. Its hydrate dissolves in acids.

b. Deutoxide of Molybdenum. $Mo O_2 = 63.726$.

A dark brown powder, forming a rust-colored hydrate, which dissolves in acids, forming red salts. When exposed to air, it absorbs oxygen and becomes blue on the surface. The blue compound is a bimolybdate of the deutoxide: $Mo O_2, 2 Mo O_2$.

c. Molybdic Acid. $Mo O_3 = 71.739$.

Obtained by roasting the sulphide at a low red-heat, as long as sulphurous acid escapes, and acting on the residue with ammonia, which dissolves molybdic acid. The molybdate of ammonia is then purified by crystallization; and on heating it gently in an open platinum crucible, ammonia is expelled, and molybdic acid left. It is a white powder, fusible at a red-heat, which sublimes in a current of air. It is sparingly soluble in water. It forms salts with bases, which are colorless.

MOLYBDENUM AND CHLORINE.

The protochloride, $Mo Cl$, is a nearly black soluble compound. When chlorine gas is passed over metallic molybdenum gently

heated, bichloride of molybdenum, Mo Cl_2 , is formed as a deep red vapor, which condenses in black crystals, like iodine. When the deutoxide is heated in dry chlorine, there is formed a yellowish-white crystalline sublimate, which is an oxychloride, analogous to that of chromium: $\text{Mo} \begin{cases} \text{O}_2 \\ \text{Cl} \end{cases}$; or $\text{Mo Cl}_2 + 2 \text{Mo O}_2$.

MOLYBDENUM AND SULPHUR.

There are 3 sulphides of this metal. 1. The bisulphide, Mo S_2 , which is the usual ore of molybdenum already described; 2. The tersulphide, a dark brown or black powder, Mo S_3 ; 3. The persulphide, also a dark powder, Mo S_4 . Both the last are sulphur acids, combining with sulphur bases, such as sulphide of potassium.

37. TUNGSTEN. $W = 99.7$.

SYN. Wolfram — Occurs in nature, chiefly in the mineral wolfram, oxidized along with oxides of iron and manganese, and more sparingly in the mineral tungsten, a compound of tungstic acid with lime. The metal may be obtained as the preceding, but is little known. It is very infusible, and has the Sp. G. 17.4. When heated in air, it burns and forms tungstic acid.

TUNGSTEN AND OXYGEN.

a. Deutoxide of Tungsten. $W O_2 = 115.726$.

To obtain it, 1 part of finely-powdered wolfram is fused in a platinum crucible, with 2 parts of carbonate of potash. Tungstate of potash is formed, which is dissolved, filtered to separate the oxides of iron and manganese, and evaporated to dryness. The salt is mixed, in solution, with half its weight of sal ammoniac, and the mixture dried up and ignited. The tungstic acid is reduced to the state of oxide by the ammonia, and chloride of potassium is formed; the latter is dissolved out by water, and the former, being first boiled with potash to remove any tungstic acid, and then washed and dried, is pure oxide of tungsten. It is a very heavy black powder, which, when heated in the air, burns like tinder, forming tungstic acid.

b. Tungstic Acid. $W O_3 = 123.739$.

It is formed, as above, by heating the oxide in the air. It is a yellow powder, insoluble in water. With bases it forms crystallizable salts. When heated to 500° or 600° in a current of hydrogen, it becomes of a fine deep blue, losing so much oxygen that it leaves an oxide, the blue oxide of tungsten, the formula of which is $W_2 O_5 = W O_2 + W O_3$; so that it may be viewed as a tungstate of tungsten.

TUNGSTEN AND CHLORINE.

When heated in chlorine gas, tungsten forms two chlorides, a bichloride, WCl_2 , and a terchloride, WCl_3 . Both are red, volatile, and crystallizable compounds, subliming in beautiful crystals. The former, with water, produces hydrochloric acid and binoxide of tungsten; the latter yields hydrochloric acid and tungstic acid.

When the binoxide is heated in chlorine gas, there is formed an oxychloride in the shape of white volatile scales, like boracic acid.

It is $WCl_3 + 2WO_2$; or $W \begin{cases} O_2 \\ Cl \end{cases}$.

The sulphides of tungsten have no peculiar interest.

38. COLUMBIUM. Ta = 185.

Syn. Tantalum. — It occurs very sparingly, in the minerals tantalite and ytthro-tantalite, as columbic acid. The metal is obtained by the action of potassium on the double fluoride of columbium and potassium, as a black powder, which, when compressed, exhibits metallic lustre; and when heated burns in air, yielding columbic acid.

With oxygen it appears to form two compounds; a binoxide, TaO_2 , and columbic acid, TaO_3 . The latter is a white insoluble powder, which forms salts with bases.

With chlorine it forms a volatile terchloride, $TaCl_3$; and with fluorine, a white soluble terfluoride, TaF_3 .

Rose is at present occupied with the study of two new metals found in the ores of columbium or tantalum, to which he has given the names of Pelopium and Niobium.

39. ANTIMONY. Sb = 129.2.

This valuable metal is chiefly found in the mineral called antimony, which is a tersulphide, SbS_3 , and which occurs both pure and combined with other sulphides. From the sulphide the metal is easily obtained by heating it with iron filings, when the sulphur combines with the iron, and the melted antimony collects at the bottom of the crucible.

It is a brittle metal, of Sp. G. 6.7, having a bluish or grayish-white color when pure. It melts at 810° , and in a very intense heat it is volatilized. When heated strongly in open vessels, it takes fire, burning with a white light, and producing white vapors, which often condense in crystals, and are sesquioxide of antimony, SbO_3 . Antimony is the chief ingredient in type metal.

ANTIMONY AND OXYGEN.

a. Teroxide of Antimony. $SbO_3 = 153.239$.

To prepare it, tersulphide of antimony is boiled with about 5 parts of strong hydrochloric acid, when sulphuretted hydrogen

is given off, and terchloride of antimony is dissolved: $\text{Sb S}_2 + 3 \text{K Cl} = \text{Sb Cl}_3 + 3 \text{H S}$. The solution is now thrown into a large quantity of water, when a curdy precipitate separates, which is teroxide of antimony, combined with some undecomposed chloride, $9 \text{Sb O}_2 + 2 \text{Sb Cl}_3$, the oxide having been formed by the action of water on the chloride: $\text{Sb Cl}_3 + 3 \text{H O} = \text{Sb O}_2 + 3 \text{H Cl}$. The precipitate of oxychloride, which soon changes into crystals, if left in the liquid, is now to be washed and digested with an excess of carbonate of soda, by which the remaining chloride is converted into oxide: $\text{Sb Cl}_3 + 3 \text{Na O} = \text{Sb O}_2 + 3 \text{Na Cl}$. The teroxide is now pure, and is to be washed and dried.

It is a grayish-white heavy powder, fusible at a dull red-heat in close vessels, and volatile at a higher temperature. If heated in the open air, it absorbs oxygen, forming antimonious acid. It is a base, and forms salts with acids, the most important of which is tartar emetic. Most of its soluble salts are decomposed by the contact of water.

Teroxide of antimony in solution is very easily recognized by the peculiar brownish-orange precipitate caused by sulphuretted hydrogen.

b. Antimonious Acid. $\text{Sb O}_2 = 161.252$.

When oxide of antimony is heated, it absorbs oxygen, and when antimonious acid is heated, it loses oxygen; the product in both cases being the permanent antimonious acid. It is a white insoluble powder, very infusible and fixed in the fire. It forms salts, called antimonites, with bases.

c. Antimonic Acid. $\text{Sb O}_3 = 169.265$.

It is formed by acting on the metal with strong nitric acid till it is converted into a white powder, which is hydrated antimonic acid. It is decomposed by a red-heat, yielding water, oxygen, and antimonious acid. It forms salts, called antimonates, with bases.

All the oxides of antimony are used in medicine; but the sesquioxide is the most important, as the basis of tartar emetic, which is a double tartrate of potash and sesquioxide of antimony.

ANTIMONY AND CHLORINE.

a. Terchloride of Antimony. $\text{Sb Cl}_3 = 235.46$.

Is readily obtained by dissolving 1 part of sulphide of antimony in 5 parts of hydrochloric acid (see above), and distilling the solution, until the volatile part becomes semi-solid on cooling; the receiver is then changed, and what passes over afterward is pure anhydrous chloride of antimony. It is a soft deliquescent solid, formerly called butter of antimony. When mixed with water, it is decomposed as mentioned above.

b. Perchloride of Antimony. $\text{Sb Cl}_5 = 306.3$.

Obtained by acting on metallic antimony, or on the sesquichloride, with an excess of chlorine. It is also formed when powdered antimony is introduced into chlorine gas, when it burns with a vivid light. It is a colorless, volatile fuming liquid, which is decomposed by water, yielding hydrochloric and antimonious acids.

c. Oxychloride of Antimony. $9 \text{ Sb O}_2 + 2 \text{ Sb Cl}_3$.

This is the white powder formed when terchloride of antimony is thrown into water, as above described, under the head of teroxide. It soon changes into crystals, and is a definite compound of oxide and chloride. It is entirely converted into oxide by alkalies. It was formerly called powder of Algaroth.

Bromine and antimony combine readily, and form a volatile crystalline solid.

ANTIMONY AND SULPHUR.

a. Tersulphide of Antimony. $\text{Sb S}_3 = 177.6$.

This is the common ore of antimony, and is generally a dark-gray radiated fusible crystalline mass, Sp. G. 4.62. When formed by the action of sulphuretted hydrogen on salts of antimony, it is precipitated as a hydrate, of a brownish orange color.

b. Persulphide of Antimony. $\text{Sb S}_5 = 209.7$.

When sesquisulphide and sulphur are boiled in solution of potash; and an acid added to the filtered liquid, a golden-yellow precipitate is formed, often called the golden sulphide of antimony, which is the persulphide, Sb S_5 .

c. Oxysulphide of Antimony. $2 \text{ Sb S}_2 + \text{Sb O}_2 = 508.2$.

This compound is found in nature as red antimony; and when sesquisulphide of antimony is boiled with potash, and an acid added to the filtered liquid, a reddish-orange precipitate is formed, which is often oxysulphide; although it may be obtained nearly free from oxide, and is then hydrated sesquisulphide. This is the substance so long known as mineral kermes; and it is the form in which sulphide of antimony is chiefly used in medicine on the Continent. In this country we use the precipitated sesquisulphide.

40. URANIUM. $\text{U} = 217$.

This metal occurs in the form of protoxide, along with other oxides in the mineral pitchblende; and in that of peroxide in uranite and uran-mica. When an excess of pitchblende is digested with diluted nitric acid, uranium dissolves, to the exclusion of iron, and after lead, copper, bismuth, or arsenic, have been removed by sulphuretted hydrogen, the solution may be considered pure. Carbonate of ammonia precipitates the peroxide of uranium, but as

excess redissolves it; and this solution, if boiled, deposits pure peroxide of uranium, of a very fine yellow color. The metal is little known; and from recent researches it would appear that what was supposed to be the metal is an oxidized body, acting, according to Pélogot, the part of a metal; while, according to others, it is the protoxide of the true metal. In the present state of our knowledge, it is not easy to decide: and as the metal is not one of great importance, I shall not enter into details here; merely stating, that the oxide formerly called protoxide, is used for giving a fine black in painting on porcelain; and that the peroxide and all its compounds have rich and permanent yellow colors. Its solutions are yellow, and give with ferrocyanide of potassium, a rich chestnut-brown precipitate.

41. CERIUM. 42. LANTANIUM.

These metals are in a state of still greater uncertainty. They occur invariably associated in some very rare minerals, and are not yet known in a state of purity. This applies to the oxides likewise. According to the most recent researches of Mosander, who discovered lanthanum, these two metals appear to be always associated with a third, didymium, which is not yet fully described. It would be absurd at present to give a description which would infallibly have to be altered in a very short time. All these metals are too rare to become of any practical interest.

43. BISMUTH. Bi = 71.07.

Occurs sometimes as metal, more frequently as sulphide. It is a highly crystalline metal, of a reddish-white color, fusible at 476° , and even volatile in close vessels. When heated in the air it burns with a bluish flame, forming oxide of bismuth. Bismuth is an ingredient in Newton's fusible metal, and in various fusible alloys.

BISMUTH AND OXYGEN.

a. Protoxide of Bismuth. Bi O = 79.083.

To obtain it, bismuth is dissolved in nitric acid, and the solution thrown into water, when a copious white precipitate of subnitrate of bismuth is formed. This is washed, dried, and ignited, and protoxide of bismuth is left. It is a yellow powder, fusible at a red-heat. With acids it forms colorless salts. Most of these salts are decomposed when thrown into water; and this character, coupled with the black caused by sulphuretted hydrogen, enables us easily to recognize the presence of bismuth, and to separate it from other metals.

b. Peroxide of Bismuth. Bi₂ O₃ = 166.179.

Formed when protoxide of bismuth is fused with hydrate of potash, or when it is digested in a solution of chloride (hypochlorite) of soda. It is a heavy brown powder, of a neutral character.

Chloride of Bismuth. $\text{Bi Cl} = 106.42$.

Powdered bismuth takes fire in chlorine gas, and forms a gray semi-solid chloride, not volatile, the old butter of bismuth.

Bromide of bismuth resembles iodine in appearance; it is fusible and volatile.

The sulphide of bismuth found in nature is of a lead-gray color; that formed by the action of sulphuretted hydrogen on the salts of bismuth is black. It is a protosulphide, Bi S .

44. TITANIUM. $\text{Ti} = 24.3$.

This metal is found oxidized in several minerals; and occurs occasionally in the metallic form, in the slag of iron works, as small cubical crystals, exactly similar to copper in appearance, of Sp. G. 5.3, and very infusible. When heated with nitre, they are oxidized, producing titanic acid.

TITANIUM AND OXYGEN.

a. Protoxide of Titanium. $\text{Ti O} =$

When a solution of titanic acid in hydrochloric acid is acted on by zinc, a purple powder is thrown down, which is supposed to be a hydrate of the protoxide. It rapidly absorbs oxygen from the air, and is reconverted into titanic acid.

b. Titanic Acid. $\text{Ti O}_2 = 40.326$.

To obtain this acid, rutile, which is a native titanate of iron and manganese, is heated to strong redness in a porcelain tube, and sulphuretted hydrogen gas passed over it, which acts on the oxides of iron and manganese, converting them into sulphides; the operation is continued as long as water is formed, and the residue is digested in hydrochloric acid, which dissolves the sulphides, leaving the titanic acid, mixed with a little sulphur. Should it not appear quite white, the process is repeated.

Titanic acid is a snow-white infusible solid, in its relations somewhat analogous to silicic acid. When it has been fused with alkali, it becomes soluble in strong hydrochloric acid, but it is precipitated by boiling. A solution of galls causes an orange-red color in its solution, and a rod of zinc causes a purple deposit. Titanic acid is used in making the finer kinds of enamel for artificial teeth, from its whiteness and hardness.

Bichloride of Titanium. $\text{Ti Cl}_2 = 59.77$.

Formed by passing chlorine gas over metallic titanium, or a mixture of titanic acid and charcoal, at a red-heat. It is a transparent colorless liquid, boiling at a little above 212° , and fuming strongly in the air. When a few drops of water are added to a portion of it, a very violent action takes place, and a solid hydrate

of titanio acid is left, hydrochloric acid being given off. $\text{Ti Cl}_3 + \text{H O} = \text{Ti O}_2 + 2 \text{H Cl}$. It absorbs a large quantity of ammonia, and yields a solid compound.

Bisulphide of titanium is formed by passing the vapor of bisulphide of carbon over titanio acid, at a white-heat: $\text{C S}_2 + \text{Ti O}_2 = \text{C O}_2 + \text{Ti S}_2$. It forms thick, green masses, which become yellow and metallic-looking by friction.

45. TELLURIUM. $\text{Te} = 64.2$.

This very rare metal occurs alloyed with gold and silver. It has a color between that of tin and lead, is very brittle, and has the Sp. G. 6.2578. It is very fusible, and volatile at a red-heat. It forms two oxides. The first, oxide of tellurium, or tellurous acid, Te O_2 , is analogous to selenious acid, and like it formed by the action of nitric acid on the metal. It is a white insoluble powder, which forms with the alcalies crystallizable salts, from which it is separated by acids as a flaky hydrate, which dissolves in acids, and even in water. It is blackened by sulphuretted hydrogen, and reduced to the metallic state by zinc and other metals. The other oxide is telluric acid, Te O_3 ; which is formed when tellurium is deflagrated with nitre. It is a soluble and crystallizable acid; the crystals are $\text{Te O}_3, 3 \text{H O}$. Its salts are not much known.

There are two chlorides: the protochloride, Te Cl , a black solid, yielding a violet vapor; and the bichloride, a white, volatile, crystallizable solid.

With sulphur, tellurium forms two compounds, one of which, the bisulphide, Te S_2 , is a dark brown powder; the other is yellow, but not permanent.

With hydrogen, tellurium forms a gaseous compound, obtained by the action of hydrochloric acid on an alloy of tellurium with zinc. It is a feeble acid, analogous in composition, smell, and other characters, to sulphuretted hydrogen. With water it forms a claret-colored solution, which precipitates many metallic salts, yielding precipitates which are tellurets of the metals, analogous to the sulphides and seleniurides. Its formula is H Te , and its action on metallic oxides is $\text{H Te} + \text{M O} = \text{M Te} + \text{H O}$.

46. COPPER. $\text{Cu} = 31.6$.

This important metal is sometimes found as metal, but it chiefly occurs in copper pyrites, the sulphide, and in blue copper ore, or malachite, which is carbonate of copper. The latter ore, heated with charcoal, yields the metal most easily. It is distinguished from all other metals, except titanium, by its red color. It melts in a strong red-heat, and has the Sp. G. 8.667. It is both ductile and malleable, and has a high degree of tenacity. It is hard, elastic, and sonorous. Heated in the open fire it absorbs oxygen,

and produces a black crust of oxide of copper, Cu O . Its proper solvent is nitric acid, but it dissolves in all acids if air be admitted, even in the cold. This renders its use for culinary purposes dangerous, as copper vessels left with vinegar, or any vegetable acid in them, are sure to be corroded, and the solutions are very poisonous. Copper is an ingredient of brass, in which it is combined with zinc; and of bronze and bell-metal, in which it is alloyed with different proportions of tin.

COPPER AND OXYGEN.

a. Protoxide of Copper. $\text{Cu O} = 39.613$.

SYN. Black Oxide of Copper — Is obtained, as above, by heating copper in air, or by calcinating nitrate of copper, when the oxide is left. It is a heavy black powder, which is a strong base, and forms with acids, salts, all of which are blue or green. The solutions of this oxide have generally a blue color: they give with potash, a pale-blue hydrate, becoming black when boiled in the liquid in which it was formed; with ammonia in excess, a deep violet-blue solution; with sulphuretted hydrogen, a black; and with ferrocyanide of potassium, a chestnut brown precipitate. The last test is highly delicate. Iron throws down metallic copper from these solutions. Black oxide of copper is not decomposed by heat, but has the valuable property of yielding all its oxygen at a red-heat to organic matter: hence its importance in organic analysis.

b. Suboxide of Copper, $\text{Cu}_2 \text{O} = 71.213$.

SYN. Red Oxide of Copper — Occurs native, and is formed when a mixture of dried sulphate of copper, dried carbonate of soda, and copper filings, is ignited strongly for 20 minutes. It is a red powder. It dissolves in hydrochloric acid, forming a colorless solution, from which alkalies precipitate an orange hydrate; but most acids resolve it into black oxide and copper. $\text{Cu}_2 \text{O} = \text{Cu O} + \text{Cu}$. It is a feeble base.

COPPER AND CHLORINE.

Chloride of Copper. $\text{Cu Cl} = 66.02$.

Forms green deliquescent needles, which are a hydrate. The anhydrous chloride is yellow.

Dichloride of Copper. $\text{Cu}_2 \text{Cl} = 98.62$.

Is found when copper-filings are heated with 2 parts of corrosive sublimate. A resinous-like, fusible mass, of a yellow or brown color.

Diniodide of Copper. $\text{Cu}_2 \text{I} = 189.7$.

Formed when iodide of potassium is added to a solution of 1 part of sulphate of copper, and 3 parts of sulphate of iron. It falls as a dirty white precipitate. We are thus enabled to precipitate

the whole of the iodine from any iodide; for if we add only sulphate of copper, not more than one-half of the iodine is got, the other half being set free, because no protoiodide of copper exists.

Disulphide of Copper. $\text{Cu}_2\text{S} = 79.32$.

This is the native ore, copper pyrites, and is formed when sulphuretted hydrogen acts on solutions of copper.

The best antidote to the preparation of copper is white of egg, which forms with oxide of copper an inert compound.

47. LEAD. $\text{Pb} = 103.6$.

This valuable metal chiefly occurs combined with sulphur, forming the mineral galena, or lead-glance, from which all the lead of commerce is obtained. It is also met with as carbonate, sulphate, phosphate, and arseniate of oxide of lead. The galena is roasted, to expel the sulphur and oxidize the lead, and the oxide is heated with charcoal to reduce the metal; indeed, a good deal of lead is obtained by heating the ore alone in a reverberatory furnace, where it is partly converted into sulphate of lead, and partly into oxide. Both of these act on undecomposed sulphide, yielding sulphurous acid and metallic lead: thus $2\text{PbO} + \text{PbS} = \text{SO}_2 + \text{Pb}_2$; and $\text{PbO}, \text{SO}_2 + \text{PbS} = 2\text{SO}_2 + \text{Pb}_2$.

Lead has a bluish-gray color, and high lustre, but soon tarnishes. Its Sp. G. is 11.381. It is malleable, ductile, soft, and flexible, but of inferior tenacity. It melts at about 612° . When heated in air it is rapidly oxidized, and, according to the heat, yields protoxide, or red oxide. The gray matter that forms on the surface of melted lead is a mixture of metal and protoxide.

Lead, when exposed to the action of air and moisture, is rapidly corroded, and particularly in contact with pure or rain-water, forming a white crust of carbonate, which is highly poisonous. The oxygen and carbonic acid are absorbed from the air. This renders lead quite improper for pipes or cisterns, where rain-water, or very soft water is to be kept in them; but Dr. Christison has shown that lead is protected by the presence of a minute quantity of saline matter, particularly sulphates, and as these exist in hard water, or even in such water as that of Edinburg, in sufficient quantity, lead may be safely used in such cases, as it is not corroded, the surface becoming covered with an insoluble film, which protects the mass of the metal.

Lead is a most useful metal, not only in itself, but as an ingredient in pewter, solder, and other important alloys.

LEAD AND OXYGEN.

Protoxide of Lead. $\text{PbO} = 111.613$.

Prepared by heating lead in air till it is entirely converted into a yellow powder, which is the protoxide, often called massicot.

When partly fused, as in the process of cupellation, it is called litharge. It is a heavy, insoluble, yellow or reddish powder, which is a base, and forms with acids the salts of lead, which are generally colorless, and have a sweet taste. Their solutions give with potash a white hydrate, soluble in excess; with carbonates, a white carbonate, which is the paint, white lead; with sulphates, or sulphuric acid, a white insoluble sulphate; with iodide of potassium, a bright yellow iodide of lead; with sulphuretted hydrogen, a dark brown, nearly black sulphide. Lead is very easily recognized in solution by the combination of the two tests of sulphuric acid and sulphuretted hydrogen, or iodide of potassium and sulphuretted hydrogen.

b. Sesquioxide of Lead. $\text{Pb}_2\text{O}_3 = 231.239$.

Is formed when solution of hypochlorite of soda is added to protoxide of lead dissolved in caustic soda. It is a reddish-yellow insoluble powder, resolved by acids into protoxide and oxygen.

c. Peroxide of Lead. $\text{PbO}_2 = 119.626$.

Prepared by acting on red oxide of lead (see below) with dilute nitric acid, which dissolves protoxide, and leaves peroxide of lead as a puce-colored insoluble powder. It is also formed when litharge is fused with chlorate of potash at as low a heat as possible; and when chlorine is passed through a solution of acetate of protoxide (sugar of lead). Here, $2\text{PbO} + \text{Cl} = \text{PbCl} + \text{PbO}_2$. The peroxide yields oxygen when heated, or when acted on by acids, which combine with protoxide, liberating oxygen.

d. Red Oxide of Lead. $\text{Pb}_3\text{O}_4 = 342.852$.

This well-known pigment is formed when lead is exposed to a current of air at 600° or 700° . It is formed either of protoxide and peroxide, $2\text{PbO} + \text{PbO}_2$; or of sesquioxide and protoxide, $\text{Pb}_2\text{O}_3 + \text{PbO}$. Acids resolve it into peroxide and protoxide. It is much used in the manufacture of flint glass, to give brilliancy and fusibility to the glass.

Chloride of Lead. $\text{PbCl} = 39.02$.

Is formed when hydrochloric acid or a soluble chloride is added to any solution of a salt of protoxide of lead: $\text{HCl} + \text{PbO} = \text{PbCl} + \text{H}_2\text{O}$. It is deposited in strong solutions as a white precipitate, sparingly soluble in cold water. It dissolves in hot water, and forms white needles on cooling. It is fusible below a red-heat, and forms on cooling a horny mass.

Iodide of Lead. $\text{PbI} = 229.9$.

Formed when hydriodic acid or a soluble iodide is added to a salt of protoxide of lead: $\text{KI} + \text{PbO}, \text{NO}_3 = \text{PbI} + \text{KNO}_3$.

It forms a bright-yellow very sparingly soluble precipitate, which dissolves in hot water, forming a colorless solution; and, on cooling, deposits beautiful yellow six-sided tables, with the lustre of gold.

Bromide of lead, Pb Br , resembles the chloride.

Sulphide of Lead. $\text{Pb S} = 119.7$.

This is the native compound from which the lead of commerce is obtained. It is gray, and has a high metallic lustre, and is often found beautifully crystallized in cubes. By the action of fuming nitric acid, it is entirely converted into sulphate of lead: $\text{Pb S} + 4 \text{NO}_3 = \text{Pb O}, \text{SO}_3 + 4 \text{NO}_2$. It is formed by the action of sulphuretted hydrogen on the salts of lead, as a black powder.

ORDER 3.—METALS, THE OXIDES OF WHICH ARE REDUCED TO THE METALLIC STATE BY A RED-HEAT.

48. MERCURY. $\text{Hg} = 202$.

This metal is distinguished from all others by its being liquid at ordinary temperatures. It is occasionally found in the metallic state; but its usual ore is the bisulphide, known as cinnabar. From this it is obtained by distilling it in iron vessels with iron filings.

The appearance of mercury or quicksilver is well known. Its Sp. G. is 13.545 at 47° : but it contracts in freezing; and as a solid, its Sp. G. is 15.612. It freezes at -39° , and boils about 620° . When heated to its boiling point along with air, it slowly combines with oxygen, forming a red powder, which is peroxide of mercury, the *oxydum hydrargyri rubrum per se* of the older chemists. At a somewhat higher temperature the oxygen again separates from the metal. The uses of mercury for barometers, thermometers, mirrors, &c., are universally known.

MERCURY AND OXYGEN.

a. Protoxide of Mercury. $\text{Hg O} = 210.013$.

To prepare it, protochloride of mercury (calomel) is rapidly mixed with aqua potassæ in excess, by rubbing in a mortar; and the black powder formed is washed with cold water and dried in the dark. $\text{Hg Cl} + \text{K O} = \text{K Cl} + \text{Hg O}$. It is a black or dark olive powder, which is easily resolved into peroxide and metal: $2 \text{Hg O} = \text{Hg O}_2 + \text{Hg}$; and hence is difficult to keep. It is a feeble base, and forms with acids crystallizable salts, such as the acetate and nitrate. Its solutions are precipitated black by caustic alkalies; white (calomel) by hydrochloric acid, or a soluble chloride; and the metal is reduced by copper, phosphorous acid, or protochloride of tin.

b. Peroxide of Mercury. $\text{HgO}_2 = 218.026$.

Is formed, as above mentioned, by the combined action of heat and air; but much more readily by dissolving mercury in nitric acid, evaporating to dryness, and heating the dry residue as long as any nitrous acid is given off. The peroxide is left in the form of a crystalline scaly powder, nearly black while hot, but of a light-red when cold. In this form it is often called red precipitate, a most absurd name, as it has not been prepared by precipitation, and when precipitated it appears as a yellow hydrate. It is a base, and forms salts with acids, which are apt to be decomposed by hot water, yielding insoluble yellow sub-salts and soluble super-salts. These salts give a yellow precipitate with caustic potash, a white with ammonia, and a fine scarlet with iodide of potassium; phosphorous acid, protochloride of tin and copper, reduce the mercury to the metallic state.

Both the oxides of mercury, in their solutions, are precipitated black by sulphuretted hydrogen.

MERCURY AND CHLORINE.

a. Protochloride of Mercury. $\text{HgCl} = 237.42$.

Syn. Calomel.—Occurs sparingly as horn quicksilver in the mineral kingdom. May be prepared either by subliming a mixture of bichloride of mercury and mercury, $\text{HgCl}_2 + \text{Hg}$, which yields 2HgCl ; or by adding hydrochloric acid or solution of common salt to a solution of protonitrate of mercury, when the protochloride is precipitated: $\text{HgO}, \text{NO}_3 + \text{NaCl} = \text{NaO}, \text{NO}_3 + \text{HgCl}$. It is a heavy white volatile powder, insoluble in water. It is blackened by alkalies. When first prepared, it is always contaminated with corrosive sublimate, and must be well washed with hot water before it is used as a medicine.

b. Bichloride of Mercury. $\text{HgCl}_2 = 272.84$.

Syn. Corrosive Sublimate.—This compound is formed when mercury is so heated as to burn in chlorine gas. It is prepared by subliming a mixture of bisulphate of peroxide of mercury with common salt: $\text{HgO}_2, 2\text{SO}_3 + 2\text{NaCl} = 2(\text{NaO}, \text{SO}_3) + \text{HgCl}_2$. Or it may be formed by dissolving peroxide of mercury in hydrochloric acid, when it is deposited in crystals. It is a heavy, translucent, crystalline, volatile solid, soluble in 20 parts of cold water, and in 2 parts of hot water. It has a very disagreeable, acid, metallic taste, and is very poisonous. Its solution gives, with fixed alkalies, a yellow precipitate of hydrated peroxide; with ammonia, a white insoluble powder, called white precipitate; with sulphuretted hydrogen, first a white, and when the test is added in excess, a black precipitate of sulphide; with

iodide of potassium, a scarlet precipitate of periodide; and with protochloride of tin, a gray powder of running mercury.

The proper antidote to corrosive sublimate as a poison, is albumen or white of egg, which forms with it an insoluble and inert compound.

MERCURY AND IODINE.

a. Protoiodide of Mercury. $\text{Hg I} = 328.3$.

This compound is formed when iodine and mercury are rubbed together in the proper proportions, with a little alcohol, which facilitates the combination; or when iodide of potassium is added to solutions of protoxide of mercury: $\text{Hg O} + \text{KI} = \text{KO} + \text{Hg I}$. It is a greenish-yellow, heavy insoluble powder, which may be sublimed; but is apt to be decomposed by heat, and especially by light, into metallic mercury and periodide: $2 \text{Hg I} = \text{Hg I}_2 + \text{Hg}$.

b. Biniiodide of Mercury. $\text{Hg I}_2 = 454.6$.

Syn. Periodide of Mercury—Is obtained by rubbing together iodine and mercury in the proper proportions, with a little alcohol, and subliming; or by adding iodide of potassium to a solution of corrosive sublimate: $\text{Hg Cl}_2 + 2 \text{KI} = 2 \text{K Cl} + \text{Hg I}_2$. It is an insoluble powder of the most brilliant scarlet color, superior to that of vermilion, and equal to that of certain flowers, such as *lobelia cardinalis*, *salvia splendens*, and certain varieties of *pelargonium*: but unfortunately it loses part of its brilliancy, when exposed to light under certain circumstances. Although insoluble in water, it dissolves easily in an excess of either of its precipitants; a hot solution of nitrate of peroxide of mercury dissolves it, and on cooling, deposits it in beautiful red crystals.

The biniiodide, when heated, undergoes a remarkable change: the red powder, which has an earthy aspect, passing into yellow crystals; and when further heated, melting and subliming in large yellow rhombic tables. Either these, or the yellow crystalline powder first mentioned, sometimes retain their yellow color pretty long; but agitation, or friction, or the mere touch of a sharp point, at once causes them to become red, beginning at a point or points, and gradually changing throughout the mass. This is the result entirely of a new molecular arrangement; for the composition of the red and yellow iodide is precisely the same.

The bromides of mercury are very similar to the chlorides.

MERCURY AND SULPHUR.

a. Protosulphide of Mercury. $\text{Hg S} = 218.1$.

Formed by the action of sulphuretted hydrogen on diluted protonitrate of mercury. It is a black powder which, by heat, is resolved into metallic mercury and bisulphide.

b. Bisulphide of Mercury. $\text{Hg S}_2 = 234.2$.

Occurs naturally, as cinnabar, and is the chief ore of mercury. Is formed by fusing sulphur with 6 parts of mercury, and subliming; or by pouring a solution of corrosive sublimate into an excess of sulphide of ammonium, when a black powder falls, which is to be dried and sublimed. When sublimed, the bisulphide forms a dark-red crystalline mass, called cinnabar, which, when finely powdered, acquires a very fine red color, and becomes vermilion.

The black powder obtained by triturating together equal parts of mercury and sulphur, and long known as Ethiop's mineral, is a mixture of sulphur with bisulphide. It is to be observed, that the bisulphide, like the biniodide, exists in two states, being sometimes black, and sometimes red.

49. SILVER. $\text{Ag} = 108.31$.

This beautiful and useful metal is found in the metallic state; also, as chloride and as sulphide. It occurs also alloyed with gold, tellurium, antimony, copper, and arsenic. Almost all varieties of galena (the ore of lead) contain a small proportion of sulphide of silver; and in many places, it is found worth while to extract this silver from the lead smelted from the ore. The separation of lead from silver is effected by cupellation; that is, by heating the alloy in a current of air, when the lead is oxidized, and the oxide is either absorbed by the cupel or porous cup; or, on the large scale, is raked away to the side, while the silver remains as a bright metallic globule, or button. From the ore in which silver occurs as metal, it is extracted by amalgamation with mercury; and the amalgam being distilled, leaves pure silver.

When the proportion of silver in lead is very small, it may be still rendered available by melting the lead, and allowing it to crystallize; the crystals which form are pure lead, and as these are separated, the silver gradually accumulates in the fluid portion. This at last comes to be very rich in silver, and is cupelled apart to obtain the latter metal.

Silver has a fine white color and high lustre. It is highly malleable and ductile, and, when pure, is a soft metal. Its Sp. G. is 10.5; it melts at a full red-heat, and when melted in open vessels, it absorbs a considerable quantity of oxygen, without apparently combining with it; and on consolidating, gives out the whole, causing the metal to assume a beautiful frosted aspect. The uses of silver are quite familiar. For the purpose of making coinage, or silver plate, it is alloyed in this country with rather less than $\frac{1}{10}$ of copper, which renders it much harder and fitter for wear.

When silver, as commonly happens, has been alloyed with copper, it is purified in several ways. 1. By dissolving the alloy in nitric acid, and adding common salt, which throws down the silver

as chloride; and from this the metal is separated (see below).
 2. By dissolving the alloy in oil of vitriol, with the aid of heat, and acting on the hot solution with metallic copper, which precipitates the silver as metal, the copper taking its place in the solution. In both processes, the small quantity of gold usually present in commercial silver, is left by the acid as a black powder, when the silver and copper are dissolved; and its extraction generally covers the whole expense of the purification of the silver, leaving, besides, a profit to the purifier.

Oxide of Silver. $\text{Ag O} = 116.323$.

This, the only oxide of silver, is obtained by dissolving silver in nitric acid, and adding caustic potash, when the oxide is precipitated as a brown powder. It may also be formed by boiling the moist, recently-prepared chloride with very strong potash, when it appears as a very dense pure black powder. It is a base, and neutralizes all acids, forming salts, most of which are insoluble, or sparingly soluble. The oxide is reduced to the metallic state by a red-heat. Its solutions are easily recognized. They give, with caustic fixed alcalies, a brown precipitate; with ammonia, a similar one, soluble in the slightest excess; with hydrochloric acid, or any soluble chloride, the white curdy precipitate of chloride of silver, insoluble in water and acids, but soluble in ammonia; and with sulphuretted hydrogen, a dark-brown, nearly black precipitate of sulphide. Silver and all its compounds are very sensitive to sulphuretted hydrogen, which blackens them. Most of the compounds of oxide of silver are very soluble in ammonia; and all the compounds of silver are darkened by the action of light, a property which has lately been applied to useful purposes in the daguerreotype, calotype, and other photographic methods. Oxide of silver is reduced to the metallic state from its solutions by copper, zinc, and several other metals. When mercury is used, there is formed a beautiful arborescent crystallization of an alloy of silver and mercury, called *Arbor Dianæ*.

When precipitated oxide of silver is acted on by ammonia, a dark powder is formed, which fulminates violently when heated, or by friction. Its composition is not exactly known; but it probably contains a compound of silver with nitrogen.

Chloride of Silver. $\text{Ag Cl} = 143.78$.

Is found in the mineral kingdom as horn silver; and is formed whenever oxide of silver comes in contact with chlorine, hydrochloric acid, or a soluble chloride. $\text{Ag} = \text{O H Cl}$ (or M Cl) = $\text{Ag Cl} + \text{H O}$ (or M O). It then forms a heavy white curdy precipitate, quite insoluble in water and acids, but soluble in ammonia. Hence, a solution of silver is a most delicate test for hydrochloric acid, or chlorides. The chloride melts at a heat below 600° , and,

on cooling, forms a translucent horny mass. The freshly precipitated chloride is very sensitive to light, and this is the foundation of Talbot's calotype.

To reduce the chloride to the metallic state, several methods are followed. 1. It is covered with water acidulated with hydrochloric acid, and a rod of zinc is introduced, which gradually reduces the whole mass of chloride: $\text{Ag Cl} + \text{Zn} = \text{Ag} + \text{Zn Cl}$. The silver is digested in dilute hydrochloric acid, washed, dried, and fused. 2. The dried chloride is fused with carbonate of potash; when carbonic acid and oxygen are given off, chloride of potassium is formed, and metallic silver collects as a button in the bottom of the crucible. In this process, the effervescence is troublesome: and if the heat be not high enough, the silver remains disseminated in the mass; while, if the heat be too high, the crucible is corroded, and the silver flows into the fire. Hence this process, although it succeeds in experienced hands, is very apt to fail in those of beginners; for which reason I have proposed the following. 3. The freshly precipitated chloride, while still moist, is boiled with very strong caustic potash, till it is converted into black oxide of silver entirely, or in great part. The oxide is then heated with a little pearl ash and borax, and yields a button without any risk of failure. The oxide thus prepared, answers admirably for making pure nitrate of silver, as diluted nitric acid dissolves it instantly, leaving undissolved any undecomposed chloride. The action of the potash in the two last processes is very simple: $\text{Ag Cl} + \text{K O} = \text{K Cl} + \text{Ag O}$.

Iodide of Silver. $\text{Ag I} = 234.88$.

Formed under the same circumstances as chloride of silver, which it resembles. It is a yellowish-white insoluble powder, insoluble in water, and nearly so in ammonia. It is very sensitive to light, and a film of iodide of silver is the substance which receives the impressions in the silver plates of the daguerreotype.

The bromide of silver is very similar to the chloride.

Sulphide of Silver. $\text{Ag S} = 124.43$.

Occurs as a mineral, silver glance, and is formed by the action of sulphuretted hydrogen on oxide of silver, or indeed on silver itself, or any compound of it whatever. Polished silver is instantly tarnished by the minutest trace of sulphuretted hydrogen, so that coal gas, which contains a mere trace of that gas, cannot be used in silversmiths' shops. It would appear that the affinity of silver for sulphur is very powerful.

50. GOLD. $\text{Au} = 199.2$.

This metal is found native, either pure or alloyed with silver and tellurium. When combined with silver, it is purified by

quartation; that is, by fusing it with so much silver, that the gold does not exceed one-fourth of the mass, and then acting on the alloy by nitric acid, which dissolves the silver, and leaves the gold as a black or brown powder, which, when fused, assumes the peculiar yellow color of gold.

Gold is distinguished by its pure yellow color, high metallic lustre and great density. Its Sp. G. is 19.3. It is the most ductile and malleable of all metals; and it melts in a strong red or white heat. From its feeble affinities, gold does not readily tarnish, and may be heated for any time without change, except when it is exposed to a strong electric spark, when it burns with a green light. No single acid dissolves it; but it is easily dissolved by chlorine and by nitro-hydrochloric acid, or aqua regia, chlorine being apparently the solvent in both cases.

GOLD AND OXYGEN.

The oxides of gold can only be obtained by indirect means.

a. Protoxide of Gold. $\text{Au O} = 207.213$.

Formed by the action of cold potash on protochloride of gold. It forms a green precipitate, which is soon resolved into peroxide and metallic gold.

b. Peroxide of Gold. $\text{Au O}_2 = 223.239$.

Obtained by adding carbonate of potash to a neutral solution of perchloride of gold, as a brownish-yellow hydrate, which at 212° loses its water and becomes black. It is a very feeble base, having apparently a tendency to combine with bases rather than with acids. When acted on by ammonia it yields fulminating gold, a very dangerous compound, which probably, like fulminating silver, contains a compound of gold with nitrogen. A binoxide of gold, Au O_2 , is supposed to exist, and to be formed as a purple powder when gold is burned by the electric spark.

GOLD AND CHLORIDE.

a. Protochloride of Gold. $\text{Au Cl} = 234.67$.

Formed by exposing the perchloride to a heat of 600° . It is a yellow insoluble powder, which by boiling in water is changed into metallic gold and perchloride. $3 \text{ Au Cl} = \text{Au}_3 + \text{Au Cl}_3$.

b. Perchloride of Gold. $\text{Au Cl}_3 = 305.61$.

This, the usual form in which gold is dissolved, is formed when gold is acted upon by aqua regia or by chlorine. It forms, when evaporated sufficiently, ruby-red crystals, which are deliquescent. The solution is yellow. It is reduced to the metallic state by many deoxidising agents, such as protosulphate of iron, formic acid and formiates, &c., &c.; and when the reduction takes place

in a diluted solution, the metallic gold appears as a blue powder as long as it is suspended in the liquid. Deoxidizing agents probably act by decomposing water, the hydrogen of which deprives the gold of chlorine. Chloride of gold is also reduced directly by the action of hydrogen, phosphuretted hydrogen, and metals. When heated it is first reduced to protochloride and afterward to metallic gold.

When solution of protochloride or sesquichloride of tin is added to solution of gold, a purple precipitate is formed, long known as the purple of Cassius, and used for staining glass. Its composition is not known with certainty, but it contains gold, tin, and oxygen.

The iodides of gold are in composition analogous to the chlorides. The sulphide, formed by the action of sulphuretted hydrogen on the perchloride, is a black powder, supposed to be a tersulphide, Au_2S_3 .

51. PLATINUM. $\text{Pt} = 98.84$.

This metal, like gold, is found in the metallic state, but always alloyed with other metals, and generally mixed, as the ore of platinum, in the form of sand, with gold, silver, and other minerals in small proportion. The purification of platinum is a tedious operation, too difficult to be described here in a few words. But the essential parts of the process are the dissolving the platinum ore in aqua regia; the precipitating the platinum as a double chloride of ammonium and platinum; and the igniting of this salt, which leaves pure platinum in a spongy state, containing, perhaps, a trace of iridium. The double chloride may also be reduced by the action of zinc and diluted sulphuric acid, when the platinum is obtained as a dense black powder. Spongy platinum is rendered malleable by being first exposed to powerful pressure, and then heated and hammered till it is rendered dense and workable. Or it may be fused before the oxyhydrogen blowpipe, being quite infusible in the furnace.

Pure platinum resembles silver, but is not so white. Its density is about 21.5, and it is both malleable and ductile, particularly the latter. It is not melted by any furnace-heat, nor acted on by air and heat together; hence its extreme utility to the chemist. When ignited with caustic alkalies, however, it is oxidized and corroded; and care should be taken never to heat any metal in vessels of platinum, as it readily forms alloys, and is much injured in consequence. The proper solvent of platinum is chlorine or aqua regia, but it dissolves less easily than gold.

One of the most important properties of platinum is its power of causing gases to enter into combination. When a current of hydrogen gas falls on spongy platinum or platinum powder in the air, combination between hydrogen and oxygen takes place at the

surface of the platinum, and the heat developed is sufficient to make the metal red-hot. The red-hot metal, then acting like any other red-hot body, sets fire to the hydrogen. This power is present even in solid polished platinum; for if a perfectly clean plate of platinum be introduced into a mixture of oxygen and hydrogen, it will cause them to combine, and may, by becoming red-hot, even produce explosion. But the power is seen in greatest perfection in the black powder of platinum; and Döbereiner has shown that this powder contains within its pores about 250 times its volume of oxygen, which, as the pores do not exceed $\frac{1}{2}$ of the powder, must occupy no more than $\frac{1}{500}$ of its bulk as gas, and must be denser than water. This explains the action on hydrogen. In the case of the polished metal it is supposed that the particles of the gases, which repel each other, are attracted by the metal, and consequently, on its surface, come within the sphere of affinity. The powder of platinum, by virtue of the oxygen in its pores, rapidly oxidizes the vapor of alcohol into acetic acid, &c.; and the smallest portion of this powder introduced into a mixture of oxygen and hydrogen causes instantaneous explosion.

OXIDES OF PLATINUM.

Platinum appears to form a green protoxide, Pt O , and a rust-colored binoxide, Pt O_2 , which, when anhydrous, is nearly black; but these compounds are even more prone to change than the oxides of gold, and the binoxide is hardly to be obtained pure, owing to its tendency to combine with the alkalies used to precipitate it. Both oxides are prepared from the chlorides.

PLATINUM AND CHLORINE.

a. Protochloride of Platinum. $\text{Pt Cl} = 134.31$.

Prepared by heating the bichloride to 450° , when the protochloride is left as a greenish-gray insoluble powder. This chloride enters into combination with ammonia, and the compound, under certain circumstances, gives rise to several very remarkable organic or quasi-organic bases, of which platinum is an element.

b. Bichloride of Platinum.

This, the usual soluble salt of platinum, is best made by dissolving spongy platinum in aqua regia, and gently evaporating to the consistence of syrup, when, on cooling, the whole forms a crystalline brownish-yellow mass, very soluble in water. The solution of platinum is characterized by yielding metallic platinum as a black powder when acted on by zinc and diluted sulphuric acid; and by giving with salts of potash and of ammonia a sparingly soluble yellow double chloride, which is also reduced by zinc and sulphuric acid.

The iodides and sulphides of platinum correspond in composition to the chlorides, but are of no practical interest. The iodides are very dark-colored, so that the addition of iodide of potassium to a solution of platinum produces a very intense reddish-brown color, gradually becoming nearly black.

52. Iridium. Ir = 98.84.

This is one of the metals which accompanies platinum. It occurs combined with osmium, alloyed with a large proportion of platinum, and occasionally nearly pure, but still containing platinum. Specimens have been found of Sp. G. 23 to 26, indicating that iridium is the heaviest of all metals. It is also the most infusible, the hardest, and that which resists best the action of acids.

These latter properties would render it most valuable if it could be wrought, but as yet it has proved refractory. It is remarkably analogous to platinum, from which it chiefly differs in the darker color of its chloride, and of the double chlorides which it forms with potassium and ammonium. The latter occurs in very dark-red octahedral crystals, nearly black, which, when heated, leave metallic iridium, very similar to spongy platinum, and acting in the same way on hydrogen.

Iridium forms 4 oxides and 4 chlorides, which are little known. They have different colors: hence the name iridium, from iris, the rainbow. The oxides are Ir O , $\text{Ir}_2 \text{O}_3$, Ir O_2 , and Ir O_3 , and the chlorides correspond to them.

53. Osmium. Os = 99.72.

This metal is found associated with iridium, constituting a small part of the ore of platinum, which is insoluble in aqua regia. When this residue is acted on at a red-heat, by nitre, both the metals are oxidized, and the mass being distilled with sulphuric acid, yields osmic acid, Os O_4 , which condenses in fusible crystals. From the acid, the metal may be obtained by the action of reducing agents, as a black powder, which becomes metallic by friction.

Osmium is very infusible, and when it has been ignited in close vessels, may be heated in air without oxidation. It is chiefly remarkable for forming with oxygen a volatile acid, which has a pungent smell, like that of chlorine, and is very poisonous. It forms, altogether, 5 oxides, Os O , $\text{Os}_2 \text{O}_3$, Os O_2 , Os O_3 , and Os O_4 ; 4 chlorides, and 4 sulphides, corresponding to the 4 first oxides.

Klaus has lately discovered, in the residue of platinum ore, along with iridium and osmium, a new metal, which from the red color of its compounds, he calls Ruthenium. It appears to be analogous to iridium, but has hitherto been little examined.

54. PALLADIUM. Pd = 58.3.

This metal is also one of those which occur in small quantity in the ore of platinum. It has lately been found rather more abundantly, alloyed with gold and silver. When the ore of platinum has been dissolved, and the solution rendered neutral by evaporation to dryness and resolution in water, a solution of bichloride of mercury causes a flocculent, grayish-yellow precipitate of cyanide of palladium. When this is ignited, the palladium is left. It is rather more fusible than platinum, which it resembles in color, lustre, and malleability, but is rather harder. Its Sp. G. is 11.3 to 11.8. From its not tarnishing, it is a valuable metal, and would be applied to many useful purposes, if it were less scarce. It is chiefly used by dentists in plates, as a substitute for gold. It is dissolved by nitric acid, but more easily by aqua regia.

Palladium forms two oxides: the protoxide Pd O , and the binoxide, Pd O_2 , both of which are black when anhydrous, and brown or yellow when hydrated. The binoxide forms fine red salts, with acids, from which the palladium is precipitated, as metal, by other metals, and by deoxidizing agents in general.

There are two corresponding chlorides, a black protochloride, Pd Cl , and a dark brown bichloride, Pd Cl_2 . The former yields with chloride of potassium a yellow double chloride, the latter a red one.

The protosulphide of palladium, Pd S , is easily formed by heating the metal with sulphur. It is a brittle fusible gray solid.

55. RHODIUM. R = 52.2.

This metal is also found, in small proportion, in the ore of platinum. It is separated from platinum, when both are in the state of chloride, by adding chloride of sodium, with which both the chlorides form double salts, of which the platinum salt is soluble, the rhodium salt insoluble, in alcohol. When purified, the rhodium salt is dissolved in water, and the rhodium precipitated by metallic zinc. It appears as a black powder, which may be fused in a powerful wind furnace, and is then white and metallic, very hard, brittle, and of Sp. G. 11.

Rhodium is hardly dissolved by any acids, unless when alloyed with other metals. The best method of dissolving it is to fuse it with bisulphate of potash, when it forms a soluble double salt. Rhodium, from its great hardness, has been used to form the tips of metallic pens, which are said to last wonderfully.

It forms two oxides; a protoxide, and a sesquioxide, $\text{R}_2 \text{O}_3$: and probably two corresponding chlorides. The solution of the sesquichloride is of a fine red color, and most of the salts of rhodium are either red or yellow.

The sulphide of rhodium is bluish-gray, metallic, and fusible at a white-heat.

ALLOYS.

The compounds of metals with metals are called alloys, and many of them are extremely useful and important. The alloys into which mercury enters, as a component part, are called amalgams.

Fine solder is an alloy of two parts of tin and one of lead. It melts at 360° . Coarse solder, which melts at 500° , contains one part of tin and three of lead. Hard solder, for copper is a compound of copper and zinc, the latter metal being in excess.

Pewter is composed of tin, with a little antimony, copper, and bismuth; the inferior kinds contain a good deal of lead.

Newton's fusible metal is composed of 8 parts of bismuth, 5 of lead, and 3 of tin. It melts below 212° .

Type metal is an alloy of 3 parts of lead, and 1 of antimony.

Bronze is composed of about 90 parts of copper to 10 of tin; bell-metal and gong-metal, of 80 parts of copper to 20 of tin. Speculum metal, for telescopes, is formed of 2 parts of copper and 1 of tin, with a little arsenic.

Brass is an alloy of copper and zinc; the best contains 4 parts of copper and 1 of zinc; and when the proportion of zinc is increased, we have tombac, Dutch gold, and pinchbeck.

Tutenague, or white copper, as it is called in China, or German silver, as it is now called in Europe, is an alloy of copper, zinc, and nickel; the finer kinds containing most nickel.

Steel appears to form valuable alloys with a very small proportion of some other metals. With a little silicon and aluminum, it yields a metal equal to the Indianwootz; and with small quantities of silver, platinum, rhodium, palladium, and even iridium and osmium, alloys of prodigious hardness and toughness are obtained. $\frac{1}{11}$ part of silver is sufficient to effect a marked improvement.

Standard silver, and standard gold, are alloys, with from $\frac{1}{12}$ to $\frac{1}{14}$ of copper, which much increases the hardness of these metals without injuring their color.

An amalgam of tin is used for silvering the backs of mirrors; and an amalgam of 4 of mercury, 2 of bismuth, 1 of lead, and 1 of tin, is used for silvering the inside of hollow glass globes.

The amalgam used for exciting electrical machines is formed of 1 part of zinc, 1 of tin, and 2 of mercury.

The tendency of mercury to combine with gold and silver is made use of in extracting these metals from their ores. An amalgam of 1 part of gold, and 8 of mercury, is used in gilding brass.

It is probable that the best alloys are those which contain atomic proportions of their ingredients; but this subject has been as yet little studied. Alloys are always more fusible than their least fusible ingredient, and they are commonly harder and more brittle than their elements. They are sometimes more dense,

sometimes less dense than we should expect from the densities of the combining metals.

SALTS.

The salts are a very important and useful class of compounds; but our space will not allow us to describe them minutely, and we must be satisfied with a few general remarks, applicable to the whole class, and with a brief statement of the characters which distinguish the separate families of salts, as marked by the acids they contain. We have already given, under the different metals, the characters of the different bases in their salts. Fortunately the analogies among the very numerous salts are so strong and well marked, that here, better than in any other department, minute details may be omitted.

When the term salt was first extended beyond sea-salt, the original type, it was applied to substances having similar properties, such as solubility, neutrality, and saline taste, with the property of crystallizing. It was found, after a time, that salts were produced by the combination of acids with alcalies, or at least by bringing them together; and as sea-salt was obtained when soda and muriatic acid were mixed, it was supposed to be formed of these constituents, just as sulphate of soda was supposed to consist of sulphuric acid and soda.

But when, in process of time, it came to be known that sea-salt contained neither muriatic acid nor soda, it was found necessary, since it was impossible to deny the claim of sea-salt to rank as a salt, to admit two kinds or classes of neutral salts, one formed of an oxygen acid and an oxygen base; the other, of a salt-radical and a metal. Thus, while sulphate of soda was Na O, SO_3 , sea-salt was Na Cl ; the former corresponding to the hydrated acid, H O, SO_3 ; the latter to the hydrogen acid H Cl . This, indeed, is the view which has for many years prevailed.

But it did not escape the sagacious mind of Davy, that, according to this view, we give two different explanations of phenomena almost identical, and that a more truly philosophical view might be taken.

When hydrated sulphuric acid acts on soda, we have two marked phenomena: these are, the formation of a neutral salt and the separation of water. This is represented as follows: $\text{Na O} + \text{H O, SO}_3 = \text{H O} + \text{Na O, SO}_3$. Now, when hydrochloric acid acts on soda, we observe exactly the same phenomena—the formation of a neutral salt, and the separation of water; but the explanation is now different. It is $\text{Na O} + \text{H Cl} = \text{Na Cl} + \text{H O}$.

Davy showed that, in the latter case, but one explanation was possible—because the hydrogen could only come from the hydrochloric acid, and the oxygen from the soda; and he proposed so to view the former case as to bring it under the same explanation.

He pointed out that we have no certainty that the hydrated sulphuric acid really contains water: nor the sulphate of soda, oxide of sodium; and that, instead of the formula H, SO_3 , we might with better reason adopt the formula, H, SO_4 for the acid, which would thus come to be considered a hydrogen acid, differing from hydrochloric acid only in containing a *compound* radical, SO_4 , instead of a *simple* one Cl . But, in the first place, chlorine may not be really a simple body; and secondly, if it were so, we know that compound radicals exist, performing exactly the part which is here ascribed to the hypothetical body SO_4 .

Thus, cyanogen, $Cy = C_2 N$, with hydrogen forms hydrocyanic acid, $H Cy$, which acts on bases exactly as hydrochloric acid does, yielding a neutral salt (a cyanide) and water. $MO + H Cy = M Cy + HO$.

Let us represent SO_4 , by Su , and then we have $HSu =$ hydrated or real sulphuric acid; and when it acts on soda, $Na O + HSu = Na Su + HO$. We have then,

	Chlorine.	Cyanogen.	Radical of Sulphuric Acid.
Radical	Cl	Cy	Su
Hydrogen Acid	$H Cl$	$H Cy$	$H Su$
Neutral Salt	$M Cl$	$M Cy$	$M Su$

In this form we see that, assuming sulphuric acid to be a hydrogen acid, the whole of its relations admit of being expressed as simply as those of hydrochloric acid. These two acids, and all acids analogous to either of them, come into the same category, and the same is true of their salts, all of which are considered compounds of metals with radicals, simple or compound. In this simple way we get rid of the absurdity of two different explanations for the same phenomena, and we arrive at the following general definition of an acid and of a salt:

An acid is the hydrogen compound of a simple or compound radical, possessing the power of neutralizing bases; and its general formula is HR .

A salt is the compound formed by replacing the hydrogen of an acid by a metal; and the general formula for a salt is MR .

This is the only view that can be taken in the case of the acids and salts of simple radicals; but in the case of compound radicals, we have already seen that another view is taken. For example, oil of vitriol is considered to be, not a hydrogen acid, but an oxygen acid united to water, and is called hydrated sulphuric acid, HO, SO_3 ; and in its salts the water is supposed to be replaced by metallic oxide, MO, SO_3 .

In favor of this, the ordinary view, it is urged that dry sulphuric acid, SO_3 , exists, and that, in contact with water, it produces hydrated sulphuric acid; in contact with bases, sulphates. That, although oil of vitriol may be viewed as H, SO_4 , this view is improbable, because the body SO_4 , the supposed radical, is

unknown in a separate form, and that many undoubted oxygen acids exist containing no hydrogen, as carbonic, silicic, phosphoric, and chromic acids.

To these considerations it may be replied, that although the body SO_2 exists, it is not truly an acid, and does not acquire acid properties until it has been in contact with water, and combined with it, that is, with hydrogen. That with ammonia, SO_2 does not form sulphate of ammonia, but an entirely different compound. That, although the supposed radical SO_4 , is unknown in a separate form, the same objection may be made to the older view in the case of nitric acid and many other acids; for strong nitric acid is viewed as a hydrate of dry nitric acid, H O, NO_3 , while dry nitric acid is quite unknown in a separate form. That those oxygen acids which exist without hydrogen, such as dry sulphuric acid, SO_3 , dry phosphoric acid, P O_3 , carbonic acid, CO_2 , silicic acid, Si O_2 , and chromic acid, Cr O_3 , either have no acid properties till water is added, as in the case of SO_3 and P O_3 , or possess very feeble and ill marked acid properties, as in the case of carbonic and silicic acids, which cannot neutralize the alkalies, and form with them an almost unlimited number of compounds. That all those oxygen acids which possess in perfection the acid character, such as oil of vitriol, nitric acid, phosphoric acid in its active state, and the whole of the organic acids, invariably contain hydrogen in a form in which it is replaced by metals in the salts, or, according to the older view, water, which in the salts is replaced by metallic oxide. Now, as in water, H O , and metallic oxide, M O , the oxygen is the same, it is, even on that view, hydrogen which is replaced by metal when an acid is converted into a salt.

It may be added, that considerations derived from the phenomena of galvanic decomposition (*Daniell*), from the heat developed when bodies combine to form salts (*Graham, Andrews*), and from the molecular or atomic volume of acids and salts (*Kopp*), all concur to render it probable that oxygen acids are hydrogen compounds, not hydrates, and that oxygen salts contain a metal united to a radical, and not an oxide united to a dry or anhydrous acid.

On the whole, therefore, the simpler view, and that which admits of but one kind of acids and one kind of salts, is, in the present state of our knowledge, to be preferred; but we shall give the formula according to both views, since we ought to be equally familiar with both.

Since salts are formed from acids by the replacement of the hydrogen of the acid by a metal, and since acids exist containing more than one equivalent of hydrogen (or of water) replaceable by metals (or metallic oxides), it is advisable to class the salts according to the acids from which they are derived, whether monobasic or polybasic.

SALTS OF MONOBASIC OXYGEN ACIDS.

Monobasic acids are those of which an equivalent forms a neutral salt with 1 eq. of base. The general formula of a monobasic acid, considered as a hydrogen acid, is HR , and its action on a protoxide is as follows: $HR + MO = HO + MR$; so that MR is the general formula for a monobasic salt. R stands here for the radical, which with hydrogen forms the acid.

On the other view, a monobasic oxygen acid is a hydrate containing 1 eq. of water and 1 eq. of dry or anhydrous acid, and the general formula is HO, RO_2 ; R standing here for the combustible element of any oxygen acid, which may be united with 2, 3, or more eq. of oxygen in the anhydrous acid. The action of such an acid on a base is as follows: $HO, RO_2 + MO = MO, RO_2 + HO$; so that, on this view, the general formula for a monobasic neutral salt is MO, RO_2 .

The most important monobasic oxygen acids, of inorganic nature, are the following: sulphuric, sulphurous, nitric, hypochlorous, chloric, perchloric, iodic, phosphoric, arsenic, arsenious, chromic, boracic, silicic, and carbonic acids, the salts of which are now to be very briefly described. The salts formed by the monobasic hydrogen acids with simple radicals have been already described, under the respective metals, as chlorides, bromides, iodides, fluorides, sulphides, &c.

SULPHATES.

General formula of neutral sulphates: M, SO_4 , or MO, SO_3 . General formula of bisulphates: $M, SO_4 + H, SO_4$; or $MO, SO_3 + HO, SO_3$.

Of the sulphates, some are found native; some are very soluble, some sparingly soluble, some insoluble. All the soluble sulphates are recognized in solution by the test of nitrate of baryta, which causes a white precipitate of sulphate of baryta, insoluble in acids. All the insoluble sulphates, when fused with carbonate of soda, yield sulphate of soda, which may be recognized as above; or, when heated with charcoal, they yield sulphides, which are easily known by their blackening the salts of lead. The action of charcoal on a sulphate is thus represented: $MO, SO_3 + C_4 = 4CO + MS$; or $M, SO_4 + C_4 = 4CO + MS$.

The sulphates of the weaker bases are decomposed by a white-heat, but those of the stronger bases are not altered.

Some neutral sulphates exist in the anhydrous state, MO, SO_3 , or M, SO_4 . Others occur combined with 1 eq. of what Graham calls constitutional water, requiring a red-heat for its expulsion, and capable of replacement by another neutral sulphate; and many occur with several equivalents of water of crystallization.

Sulphate of potash crystallizes in six-sided prisms and pyramids which are anhydrous. Its formula is KO, SO_3 , or K, SO_4 .

Bisulphate of potash crystallizes in fine needles, the formula of which is $(K O, S O_3 + H O, S O_3)$; or $K, S O_4 + H, S O_4$. It is a very acid salt, and is much used as a flux in mineral analysis.

Sulphate of soda, or Glauber's salt, forms large prisms, the formula of which is $Na O, S O_3 + 10 aq.$; or, $Na, S O_4 + 10 aq.$ It is used as a laxative; and from this salt in its anhydrous state, (prepared from sea-salt by the action of oil of vitriol,) carbonate of soda is manufactured by heating it with charcoal in a reverberatory furnace.

Sulphate of ammonia ($N H_3, H O, S O_3$), or $N H_4, S O_4$), crystallizes in the same form as sulphate of potash. With water of crystallization it forms crystals of a totally different form, $N H_4, O + S O_3 + aq.$

Sulphate of baryta, or heavy spar, occurs native in large tabular and also prismatic crystals. It is remarkable for its insolubility in water and acids. It is decomposed by ignition with charcoal, yielding sulphide of barium, from which all the other compounds of barium may be obtained. It is anhydrous, and its formula is $Ba O, S O_3$, or $Ba, S O_4$.

Sulphate of strontia, or celestine, also occurs native and is very analogous to the preceding. It serves, when decomposed by ignition with charcoal, to yield all the compounds of strontium. Formula, $Sr O, S O_3$, or $Sr S O_4$.

Sulphate of lime. This salt occurs native as gypsum, selenite, and alabaster, the formula of which is $(Ca O, S O_4 + H O) + aq.$; or $(Ca, S O_4 + H O) + aq.$ In the mineral anhydrite, it is anhydrous, $Ca O, S O_3$, or $Ca, S O_4$. When heated to 270° , gypsum loses both its constitutional water and its water of crystallization, and falls to a fine powder which is plaster of Paris; and which when mixed with water, combines with it again, forming a solid compound or setting, as it is called. Hence its use in moulding. Gypsum is also a very valuable manure. It is sparingly soluble in water, but its solution is precipitated copiously by salts of baryta.

Sulphate of magnesia, or Epsom salts, occurs in some springs, and is easily made by dissolving carbonate of magnesia in sulphuric acid. It is very soluble, and crystallizes readily in four-sided prisms, the formula of which is $(Mg O, S O_3 + H O) + 6 aq.$ It is much used as a laxative.

Sulphate of alumina does not crystallize, but it enters into the composition of crystallizable double salts, called alums. Its formula is $Al_2 O_3, 3 S O_3$, or $Al_2, 3 S O_4$.

A subsulphate, or trisulphate of alumina, occurs native as the mineral aluminite. Formula, $Al_2 O_3, S O_3 + aq.$

Sulphate of manganese forms pale pink or colorless crystals, of the formula $(Mn O, S O_3 + H O) + 4 aq.$; or, $(Mn, S O_4 + H O) + 4 aq.$

Sulphate of iron, (protoxide) or green vitriol. This well-known salt forms pale green oblique prisms. Formula, $(\text{Fe O}, \text{S O}_3 + \text{H O}) + 5 \text{ aq.}$; or $(\text{Fe S O}_4 + \text{H O}) + 5 \text{ aq.}$ It is used in the manufacture of fuming sulphuric acid, hence called oil of vitriol; in making ink; and very extensively in dyeing, and calico-printing. It is also much used in medicine.

Sulphate of the peroxide of iron does not crystallize, but forms crystallizable double salts. Formula, $\text{Fe}_2 \text{ O}_3, 3 \text{ S O}_3$; or $\text{Fe}_2, 3 \text{ S O}_4$.

Sulphate of zinc, or white vitriol, forms crystals exactly similar to those of sulphate of magnesia. Formula, $(\text{Zn}, \text{S O}_3 + \text{H O}) + 6 \text{ aq.}$; $(\text{Zn}, \text{S O}_4 + \text{H O}) + 6 \text{ aq.}$ It is much used in surgery, and is formed when zinc is dissolved in diluted sulphuric acid.

Sulphate of nickel forms emerald-green crystals of the same form as the preceding. Formula, $(\text{Ni O}, \text{S O}_3 + \text{H O}) + 6 \text{ aq.}$; or $(\text{Ni}, \text{S O}_4 + \text{H O}) + 6 \text{ aq.}$

Sulphate of cobalt forms rose-red crystals of the same form as green vitriol. Formula, $\text{Co O}, \text{S O}_3 + \text{H O}) + 5 \text{ aq.}$; or $\text{Co}, \text{S O}_4 + \text{H O}) + 5 \text{ aq.}$

Sulphate of chromium does not crystallize, but forms crystallizable double salts. Formula, $\text{Cr}_2 \text{ O}_3, 3 \text{ S O}_3$; or $\text{Cr}_2, 3 \text{ S O}_4$.

Sulphate of copper, or blue vitriol, forms azure-blue crystals, exactly of the same form of those of the sulphate of manganese. Its formula is $(\text{Cu O}, \text{S O}_3 + \text{H O}) + 4 \text{ aq.}$; or, $(\text{Cu}, \text{S O}_4 + \text{H O}) + 4 \text{ aq.}$ With excess of ammonia it forms a deep violet-blue salt, the ammoniuret of copper, in which the water of crystallization of blue vitriol, or part of it appears to be replaced by ammonia. Sulphate of copper is much used as an escharotic in surgery.

Sulphate of peroxide of mercury is formed as a crystalline powder, when mercury is boiled to dryness with sulphuric acid. Its formula is $\text{Hg O}_2, 2 \text{ S O}_3$, or $\text{Hg}, 2 \text{ S O}_4$. It is used in the preparation of corrosive sublimate and of calomel.

Sulphate of silver forms anhydrous crystals, having the same form as those of anhydrous sulphate of soda. Formula, $\text{Ag O}, \text{S O}_3$, or $\text{Ag}, \text{S O}_4$.

DOUBLE SULPHATES.

Of these there are two well marked groups. The type of the first is sulphate of magnesia, and potash; the type of the second is sulphate of alumina and potash, or alum.

1. When sulphate of potash and sulphate of magnesia are mixed in equivalent proportions, and the solution evaporated, crystals are deposited of a well-marked form, the formula of which is $(\text{K O}, \text{S O}_3 + \text{Mg O}, \text{S O}_3) + 6 \text{ aq.}$; or $(\text{K}, \text{S O}_4 + \text{Mg}, \text{S O}_4) + 6 \text{ aq.}$ It appears to have been formed from sulphate of magnesia, by the substitution of $\text{K O}, \text{S O}_3$, for the constitutional H O , the 6 aq. remaining unchanged. It is but the type

of a large group; for similar double salts may be formed with sulphate of potash, and the sulphates of zinc, nickel, cobalt, iron, copper, and manganese; and another series, of exactly the same form, may be obtained by substituting sulphate of ammonia for sulphate of potash; as, for example, in the double sulphate of magnesia and ammonia ($\text{NH}_4, \text{O}, \text{SO}_3, + \text{Mg O}, \text{SO}_3$) + 6 aq.

2. Common alum, the type of the second group, is formed when sulphate of potash combines with sulphate of alumina, and its formula is ($\text{K O}, \text{SO}_3 + \text{Al}_2, \text{O}_3, 3 \text{SO}_3$) + 24 aq.; or ($\text{K}, \text{SO}_4 + \text{Al}_2, 3 \text{SO}_4$) + 24 aq. Now this is also the type of a numerous group; for the potash may be replaced by the soda or ammonia, and the alumina may be replaced by the sesquioxides of iron, manganese, and chromium. The general formula of this group is ($\text{M O}, \text{SO}_3 + m_2 \text{O}_3, 3 \text{SO}_3$) + 24 aq.; M representing potassium, sodium, or ammonium, and m, aluminum, iron, manganese, or chromium. All the salts of this group which are called alums, crystallize in octahedrons, and contain the same amount of water.

When we consider the facts above noticed, the circumstance that the sulphates of copper and manganese, with 4 eq. of water of crystallization, those of iron and cobalt, with 5 eq., and those of magnesia, zinc, and nickel, with 6 eq. respectively crystallize in the same forms, different for each group; and when we reflect on the two remarkable groups of double sulphates just described, we cannot avoid the conclusion, that similarity of constitution is one main cause of similarity of crystalline form; and this constitutes the doctrine of isomorphism, as at present understood and admitted. By similarity of constitution is meant, not only a likeness in the nature of the elements present, but a similar arrangement of those elements.

Thus, in common alum, $\text{K O}, \text{SO}_3 + \text{Al}_2 \text{O}_3, 3 \text{SO}_3 + 24 \text{ aq.}$; and in ammonia, iron, alum, $\text{Am O}, \text{SO}_3 + \text{Fe}_2 \text{O}_3, 3 \text{SO}_3 + 24 \text{ aq.}$; not only is ammonium (Am) analogous to potassium, and iron to aluminum, but the new elements occupy the same position as the original ones, as is shown by the formula.

SULPHITES.

The sulphites are recognized by their giving off the suffocating smell of sulphurous acid when acted on by a stronger acid. They have lately been studied by Muspratt, who has found that a very close analogy exists between the sulphites and the carbonates.

NITRATES.

The nitrates are prepared by the action of nitric acid on bases, on metals or on carbonates. They are all decomposed by a red-heat, and they all deflagrate with red-hot charcoal. In solution, they are best recognized by adding sulphuric acid and warming, which sets free the nitric acid, and then cautiously adding solution

of green vitriol, which at the line of the junction of the two liquids becomes black or red, according to the proportion of nitric acid, from its peculiar action on the protosalts of iron. The general formula of nitrates in the anhydrous state is $M O, N O_3$, or M, O_3 .

Nitrate of potash, nitre or saltpetre, is found as an efflorescence on the soil in hot climates, and may be formed artificially in nitre beds. The essential conditions are the presence of a fixed base, particularly potash; and of decaying organic matter, or some other source of ammonia, which is oxidized, producing nitric acid and water; and the acid then unites with the base. The ammonia $N H_3$, with 8 eq. of oxygen from the air, gives rise to nitric acid and water, $N O_3 + 3 H O$, or $H, N O_3 + 2 H O$. There is no reason to believe that the nitrogen of the atmosphere is ever oxidized, or contributes to nitrification; and the minute trace of nitric acid sometimes observed in the rain of thunder-storms, has in all probability been formed from the ammonia of the atmosphere.

Nitre crystallizes in 6-sided prisms. It is much used in making gunpowder, and as an oxidizing agent; also in the manufacture of nitric acid. Formula, $K O, N O_3$, or $K, N O_3$.

Nitrate of soda is formed precisely in the same way, where soda is the base present in the soil, and occurs in immense quantities in some parts of South America. It crystallizes in rhombohedrons. It is much used in the manufacture of sulphuric and nitric acids, but does not answer for gunpowder. Formula, $Na O, N O_3$, or $Na, N O_3$.

Both nitre and nitrate of soda are used as manures: and it is still uncertain whether the acid of these salts contributes to the good effect, or whether they act by the bases alone.

Nitrate of ammonia crystallizes in prisms like those of nitrate of potash. It is used in the preparation of the protoxide of nitrogen or laughing gas. Formula, $N H_4 O, N O_3$ or $N H_4, N O_3$.

Nitrate of baryta crystallizes in octahedrons, which are anhydrous. It is much used as a test, and when ignited yields pure baryta. Formula, $Ba O, N O_3$, or $Ba, N O_3$.

Nitrate of strontia forms anhydrous crystals, isomorphous with the preceding salt; but it also occurs in large prismatic crystals, containing 5 eq. of water. It is used in the manufacture of red fire.

Nitrate of lime and nitrate of magnesia crystallize with difficulty, and are extremely deliquescent.

Nitrate of copper forms deep blue crystals, the formula of which is $Cu O, N O_3 + 3 H O$, or $Cu, N O_3 + 3 H O$. There is also a subnitrate, the formula of which is $H O, N O_3 + 3 Cu O$: the former salt may be viewed as nitrate of copper with 3 eq. of constitutional water, the latter as nitrate of water, with 3 eq. of con-

stitutional oxide of copper. When either is ignited, it leaves pure oxide of copper, well adapted for organic analysis.

Nitrate of lead crystallizes in octahedrons, and is isomorphous with the nitrates of baryta and strontia. Formula, PbO, NO_3 , or Pb, NO_3 .

Nitrate of mercury is of uncertain composition: there seem to be nitrates both of protoxide and peroxide, but both have a great tendency to form subsalts, especially in contact with water. When heated, the acid is driven off, and peroxide of mercury is left.

Nitrate of silver, or lunar caustic, is very much used as an escharotic. It is made by dissolving pure silver, or the oxide formed from the chloride (see p. 226) in nitric acid and evaporating, when crystals are deposited, which are fine tables, anhydrous, and fusible at 426° , when they may be run into a mould so as to yield the sticks of caustic. Formula, AgO, NO_3 , or Ag, NO_3 . It is the chief ingredient of indelible ink. Like all the other compounds of silver, it is blackened by light, especially when in contact with organic matter. It is much used as a test for chlorine.

CHLORATES.

The chlorates are, both in formula and properties, very analogous to the nitrates. They deflagrate violently with combustible matter, and are easily distinguished from nitrates by leaving chlorides when ignited. Their general formula is MO, ClO_3 , or M, ClO_3 .

The only important chlorate is chlorate of potash, the theory of the production of which has been already explained (see p. 94). It forms tabular crystals, of a pearly lustre. It is chiefly used as a convenient source of very pure oxygen gas, and as an oxidizing agent. Its formula is KO, ClO_3 , or K, ClO_3 .

The perchlorate of potash, KO, ClO_7 , or K, ClO_7 , is the only perchlorate of interest. It is so sparingly soluble that perchloric acid may be used as a test for potash. It deflagrates with combustible matter, although not so powerfully as the chlorate.

HYPOCHLORITES.

These salts do not, in themselves, possess much importance, but are interesting as forming part of the bleaching compounds of lime and soda, so much used in the arts. These bleaching compounds, as explained at pp. 94 and 95, are formed when chlorine acts on an alkali or alkaline earth, and may be viewed either as composed of a hypochlorite and a chloride, or as oxychlorides of the metal. According to the former view, which is the more probable, bleaching-powder is $(\text{CaO}, \text{ClO}) + \text{CaCl}$. When acted on by an acid, the whole of its chlorine is set free, and hence its enormous bleaching power when an acid is used: hence, also, its want of bleaching power, unless acid is added.

The action of sulphuric acid is as follows: $(\text{Ca O}, \text{Cl O} + \text{Ca Cl}) + 2 \text{S O}_2 = 2 (\text{Ca O}, \text{S O}_2) + \text{Cl}_2$. According to the latter view, bleaching powder is Ca O Cl , an oxychloride, and the action of sulphuric acid is $\text{Ca O Cl} + \text{S O}_2 = \text{Ca O}, \text{S O}_2 + \text{Cl}$.

Chloride of soda, a perfectly analogous compound, is either $\text{Na O}, \text{Cl O} + \text{Na Cl}$, or Na O Cl ; and its action with sulphuric acid is explained exactly as above.

IODATES.

These salts are, in general, analogous to the chlorates, but are of little practical importance. The general formula for an iodate is $\text{M O}, \text{I O}_2$, or $\text{M}, \text{I O}_2$. When heated to redness, oxygen is given off, and an iodide remains.

The bromates are quite analogous to the chlorates. General formula, $\text{M O}, \text{Br O}_2$, or $\text{M}, \text{Br O}_2$.

PHOSPHATES.

There are three distinct modifications of phosphoric acid, each of which forms its own salts. Indeed, were it not that these acids, under certain circumstances, may be made to pass into each other, we should never think of describing them otherwise than as totally distinct acids. The three acids are, monobasic, bibasic, and tribasic phosphoric acids.

The so-called anhydrous phosphoric acid, formed by burning phosphorous in dry air or oxygen, is not, strictly speaking, an acid, and does not acquire acid properties till it has taken up the elements of at least 1 eq. of water, when it becomes monobasic phosphoric acid.

According to the usual view, the three acids are $\text{P O}_2, \text{H O}$, $\text{P O}_2, 2 \text{H O}$, and $\text{P O}_2, 3 \text{H O}$, thus containing, all of them, anhydrous acid united with different proportions of water. Now this is quite conceivable, and we actually possess three distinct hydrates of sulphuric acid, $\text{S O}_2, \text{H O}$; $\text{S O}_2, 2 \text{H O}$; and $\text{S O}_2, 3 \text{H O}$. But we find, further, that the acid $\text{P O}_2, \text{H O}$ requires but 1 eq. of base, to form a neutral salt, while the acid $\text{P O}_2, 2 \text{H O}$ requires 2 eq.; and the acid $\text{P O}_2, 3 \text{H O}$, 3 eq. of base to form neutral salts. In the case of sulphuric acid the same phenomenon does not occur, for all the hydrates are neutralized by 1 eq. of base, yielding the same salt, and not, as the phosphoric acids do, different salts. What is the cause of this difference? It is not enough to say that the dry acid, P O_2 , being in the monobasic form combined with 1 eq. of water, has a tendency to take 1 eq. of base, and so on; for this is merely restating the fact in other words; and, besides, no such tendency is observed in sulphuric acid and in many other acids.

It appears to me that the only satisfactory answer to the question is the following. The three acids are all distinct acids, and

none of them contains anhydrous phosphoric acid. They are all hydrogen acids; and their respective formulæ are $\text{P O}_5, \text{H}$; $\text{P O}_7, \text{H}_2$; and $\text{P O}_9, \text{H}_3$. Now as every hydrogen acid forms a neutral salt by the substitution of a metal for the hydrogen, these acids, if they exist, must require respectively, 1, 2 and 3 eq. of base to neutralize them, and must of course, produce totally distinct salts: according to the equations, $\text{P O}_5, \text{H} + \text{M O} = \text{P O}_5, \text{M} + \text{H O}$; $\text{P O}_7, \text{H} + 2 \text{M O} = \text{P O}_7, \text{M}_2 + 2 \text{H O}$; and $\text{P}_2 \text{ O}_9, \text{H}_3 + 3 \text{M O} = \text{P O}_9, \text{M}_3 + 3 \text{H O}$.

MONOBASIC PHOSPHATES.

According to the above views, therefore, the general formula for a monobasic phosphate is $\text{P O}_5, \text{M}$, or $\text{P O}_5, \text{M O}$. Monobasic phosphate of soda, $\text{P O}_5, \text{Na}$, or $\text{P O}_5, \text{Na O}$, is obtained by heating the acid tribasic phosphate of soda to redness, when it loses 2 eq. of water, and monobasic phosphate is left. It is soluble but not crystallizable, and gives, with chloride of barium, a bulky precipitate, which is $\text{P O}_5, \text{Ba}$, or $\text{P O}_5, \text{Ba O}$; and with nitrate of silver, a flaky white precipitate, which is $\text{P O}_5, \text{Ag}$, or $\text{P O}_5, \text{Ag O}$.

BIBASIC PHOSPHATES.

Of these there are two series, as one of the 2 eq. of base may be basic water, or both may be fixed base. The general formulæ for the two series are $\text{P O}_7, \text{M}_2$, or $\text{P O}_7, 2 \text{M O}$; and $\text{P O}_7, \left\{ \begin{smallmatrix} \text{H} \\ \text{M} \end{smallmatrix} \right\}$ or $\text{P O}_5, \left\{ \begin{smallmatrix} \text{H O} \\ \text{M O} \end{smallmatrix} \right\}$. Bibasic phosphate of soda, $\text{P O}_7, \text{Na}_2$, or $\text{P O}_5, 2 \text{Na O}$, is obtained by exposing to a red-heat common tribasic phosphate of soda, which loses 1 eq. of water, and is converted into the new salt. It is soluble and crystallizable, and gives, with nitrate of silver, a granular white precipitate, which is $\text{P O}_7, \text{Ag}_2$, or $\text{P O}_5, 2 \text{Ag O}$. When the acid tribasic phosphate of soda is heated to 400° , it loses 1 eq. of water, and leaves the acid bibasic phosphate, $\text{P O}_7, \left\{ \begin{smallmatrix} \text{H} \\ \text{Na} \end{smallmatrix} \right\}$ or $\text{P O}_5, \left\{ \begin{smallmatrix} \text{H O} \\ \text{Na O} \end{smallmatrix} \right\}$.

TRIBASIC PHOSPHATES.

Of these, which are the most usual phosphates, there are three series, the general formulæ for which are as follows: $\text{P O}_9, \text{M}_3$, or $\text{P O}_9, 3 \text{M O}$: $\text{P O}_9, \left\{ \begin{smallmatrix} \text{H} \\ \text{M}_2 \end{smallmatrix} \right\}$ or $\text{P O}_9, \left\{ \begin{smallmatrix} \text{H O} \\ 2 \text{M O} \end{smallmatrix} \right\}$: and $\text{P O}_9, \left\{ \begin{smallmatrix} \text{H}_2 \\ \text{M} \end{smallmatrix} \right\}$ or $\text{P O}_9, \left\{ \begin{smallmatrix} 2 \text{H O} \\ \text{M O} \end{smallmatrix} \right\}$.

Common phosphate of Soda belongs to the second series: it is $\text{P O}_9, \left\{ \begin{smallmatrix} \text{H} \\ \text{Na}_2 \end{smallmatrix} \right\}$ or $\text{P O}_9, \left\{ \begin{smallmatrix} \text{H O} \\ 2 \text{Na O} \end{smallmatrix} \right\}$ when dry, to which, in the crystals, are added 24 eq. of water of crystallization, by the addition of

caustic soda, it is converted into P O_5 , Na_3 , or P O_5 , 3 Na O ; and by the addition of phosphoric acid, until it ceases to precipitate chloride of barium, it is converted into the acid tribasic salt, $\text{P O}_5 \left\{ \begin{smallmatrix} \text{H}_2 \\ \text{Na} \end{smallmatrix} \right.$ or $\text{P O}_5 \left\{ \begin{smallmatrix} 2 \text{ H O} \\ \text{Na O} \end{smallmatrix} \right.$. With nitrate of silver, either of these salts yields a lemon-yellow precipitate, which is tribasic phosphate of silver, P O_5 , Ag , or P O_5 , 3 Ag O .

Microcosmic salt, much used as a blowpipe re-agent, is a tribasic phosphate, $\text{P O}_5 \left\{ \begin{smallmatrix} \text{H} \\ \text{Na} \\ \text{N H}_4 \end{smallmatrix} \right.$ + 8 aq. or $\text{P O}_5 \left\{ \begin{smallmatrix} \text{H O} \\ \text{Na O} \\ \text{N H}_4 \text{ O} \end{smallmatrix} \right.$ + 8 aq.

N H_4 here represent ammonium.

Bone phosphate of lime is a peculiar compound, $(8 \text{ Ca O} + 3 \text{ P O}_5 + \text{H O}) = (\text{P O}_5 \left\{ \begin{smallmatrix} \text{H} \\ \text{Ca}_2 \end{smallmatrix} \right. + 2 (\text{P O}_5, \text{Ca}_3))$; or $\text{P O}_5 \left\{ \begin{smallmatrix} \text{H O} \\ 2 \text{ Ca O} \end{smallmatrix} \right.$ + 2 P O_5 , 3 Ca O , and may be viewed as a compound of two forms of tribasic phosphate of lime.

The double phosphate of ammonia and magnesia, which occurs in some urinary calculi, and is also found in the husk of grain and other vegetable products, appears to be an anomalous phosphate, containing $(\text{P O}_5, 2 \text{ Mg O}, 2 \text{ N H}_3, 10 \text{ H O})$, but how arranged is not known.

This salt always separates as a sparingly soluble or insoluble granular precipitate, when phosphoric acid, ammonia, and magnesia meet in neutral or alkaline solutions, and therefore its formation may be made a test, either of the presence of phosphoric acid, or of that of magnesia.

I have lately (see the process for preparing pure phosphoric acid from bones, page 128) obtained a new phosphate of magnesia. It is quite insoluble, and its formula is $3 \text{ P O}_5 + 2 \text{ Mg O}$, or, adopting the higher atomic weight for phosphorus (see page 134), $3 \text{ P O}_5 + 3 \text{ Mg O}$.

This is a most remarkable composition, because it is quite anomalous, if we adopt the views above developed on the constitution of the phosphates. We cannot consider it as a monobasic, a bibasic, or a tribasic phosphate.

We may, it is true, adopting the older views regarding phosphoric acid, and rejecting all that we have learned concerning the three modifications of that acid, view it as an acid sesquiphosphate of magnesia. But it is easy to see that this view is quite irreconcilable with that which we must adopt regarding all other known phosphates. It is, therefore, possible, not to say probable, that this salt, being formed at a certain temperature, may contain a fourth modification of phosphoric acid; which will be $\text{P}_6 \text{ O}_{15}$, 2 H O , when free, and the salts of which will be $\text{P}_6 \text{ O}_{15}$, 2 M O , or $\text{P}_6 \text{ O}_{15} \left\{ \begin{smallmatrix} \text{M O} \\ \text{H O} \end{smallmatrix} \right.$. This point requires further investigation.

ARSENATES.

The salts of arsenic acid are extremely analogous to those of tribasic phosphoric acid ; indeed they are so similar in form, color, solubility, &c., that to distinguish the arseniate of a base from the corresponding tribasic phosphate, we must ascertain the presence of arsenic.

The only ascertained case in which a well-marked difference in external properties exists, is in the case of the arseniate of silver, which, instead of being yellow, like the corresponding tribasic phosphate, is of a dark, brick red color. The arseniates are tribasic, and their general formulæ are, $\text{As O}_3, \text{M}_3$; or $\text{As O}_3, 3 \text{M O}$:
 $\text{As O}_3 \left\{ \begin{smallmatrix} \text{H} \\ \text{M}_3 \end{smallmatrix} \right.$ or $\text{As O}_3 \left\{ \begin{smallmatrix} \text{H O} \\ 2 \text{M O} \end{smallmatrix} \right.$ and $\text{As O}_3 \left\{ \begin{smallmatrix} \text{H}_2 \\ \text{M} \end{smallmatrix} \right.$ or $\text{As O}_3 \left\{ \begin{smallmatrix} 2 \text{H O} \\ \text{M O} \end{smallmatrix} \right.$
 Several arseniates are found native.

CHROMATES.

These salts are yellow, orange, or red, the latter color predominating when the acid is in excess, except in the case of dichromate of lead, which is red. The soluble chromates are recognized by their color, which is changed to green when alcohol and hydrochloric acid are added, and the mixture is boiled. The general formula for neutral chromates is $\text{M O}, \text{Cr O}_3$; and for bichromates, $\text{M O}, 2 \text{Cr O}_3$.

Neutral chromate of potash, $\text{K O}, \text{Cr O}_3$, forms beautiful yellow crystals, isomorphous with sulphate of potash. It is formed by neutralizing the bichromate with potash.

Bichromate of potash, $\text{K O}, 2 \text{Cr O}_3$, is much used in calico-printing, and is obtained by fusing chromine iron ore with nitre. The ore contains sesquioxide of chromium, $\text{Cr}_2 \text{O}_3$, which is oxidized by the nitre into chromic acid, $\text{Cr}_2 \text{O}_3 = 2 \text{Cr O}_3$, and this combines with the potash of the nitre to form neutral chromate. This is dissolved and filtered, and the warm solution acidulated with acetic acid, which takes half the potash, and, on cooling, the bichromate is deposited in beautiful red crystals.

Both these salts, especially the bichromate, have a very deleterious action on the system, when their solutions are brought much in contact with the skin, causing sores, which are very painful and difficult to heal. Paper impregnated with these salts, and dried, forms excellent tinder. The solutions have very powerful antiseptic properties.

Dichromate of lead, $2 \text{Pb O} + \text{Cr O}_3$, is found native, as the red lead ore, forming beautiful red crystals. It may also be formed by fusing the neutral chromate of lead with nitrate of potash, or by boiling carbonate of lead with chromate of potash; and is much used as a paint.

Chromate of lead, $\text{Pb O}, \text{Cr O}_3$, is an insoluble powder, of a very fine yellow color, much used in painting, under the name of

chrome yellow. It is formed by the action of soluble salts of lead on chromate, or bichromate of potash.

Chromate of silver, Ag O , Cr O_3 , forms dark green crystals, which are red by transmitted light, and yield a deep red powder. When precipitated, the salt is of a rich dark red.

Bichromate of silver forms crimson-red tabular crystals Ag O , 2 Cr O_3 . Chromate of mercury, Ag O , Cr O_3 , is a light red powder, which, when ignited, leaves sesquioxide of chromium of a very fine green color.

BORATES.

The only important borate is borax, which is a biborate of soda, Na O , $2 \text{ B O}_3 + 10 \text{ aq.}$ It is found native but very impure, in Thibet, and is purified in Europe. It is also now formed by adding soda to the native boracic acid obtained from hot springs in Tuscany. Boracic acid is so feeble an acid that even the 2 eq. of it in borax do not fully neutralize the soda, so that borax is an alkaline salt. The borate of soda, with 1 eq. of acid, Na O , $\text{B O}_3 + 8 \text{ aq.}$, is a strongly alkaline salt.

Borax is much used as a flux, on account of its ready fusibility, and its high solvent power, at a red-heat.

CARBONATES.

These salts are recognized by their being decomposed with effervescence, the gas disengaged having no offensive smell, when acted on by acids. All the soluble carbonates, even those containing 2 eq. of acid to 1 of base, are alkaline, so that the title of carbonic acid to the name of acid is doubtful.

Carbonate of potash, K O , CO_2 , is anhydrous, deliquescent, not crystallizable, insoluble in alcohol. It is obtained pure by igniting cream of tartar, and lixiviating the residue. In an impure state it constitutes pearlash and potashes, which, are, as the name implies, the ashes of plants. Carbonate of potash is much used as a flux in mineral analysis, and for the preparation of caustic potash, and other salts of potash; also in the manufacture of soap, and of glass.

Bicarbonate of potash $\text{K O C O}_2 + 2 \text{ aq.}$, is obtained by exposing a strong solution of the carbonate to a current of carbonic acid, or to the atmosphere of a fermenting vat, when the bicarbonate is deposited in crystals. The purest carbonate is obtained by igniting these crystals.

Carbonate of soda, Na O , $\text{CO}_2 + 10 \text{ aq.}$, forms very large rhomboidal crystals, which effloresce in the air. It was formerly extracted from kelp or barilla, which is the ashes of marine plants, but it is now made from sea-salt, far more cheaply, and in a state of perfect purity. The salt, Na Cl , is first converted into sulphate of soda, Na O , SO_3 , by being heated with oil of vitriol. The sulphate of soda is now mixed with saw-dust and lime, and heated in

a reverberatory furnace. By this means the sulphuric acid is decomposed, its sulphur partly uniting with calcium, and partly escaping as sulphurous acid, while the carbonic acid which is formed unites with soda. The carbonate is purified by crystallization, but generally retains a trace of sulphuric acid.

Carbonate of soda is very much used in the making of soap and glass, being both much cheaper and much purer than ordinary potash. It is also much employed by washerwomen to render hard water soft, and in general to assist in washing, as it is powerfully detergent.

Bicarbonate of soda, $\text{Na O}, \frac{1}{2} \text{CO}_2 + \text{aq.}$, forms a white powder, which is alkaline, and is much used in medicine as a mild antacid, and as one of the ingredients in effervescing or Seidlitz powders.

The common commercial and medicinal carbonate of ammonia is a sesquicarbonate, $2 \text{NH}_3 + 2 \text{H O} + 3 \text{CO}_2$. It is formed by heating a mixture of 2 parts of sal ammoniac and 3 of dried chalk, and sublimes as a hard crystalline volatile mass, having a strong smell of ammonia. When exposed to air, it loses ammonia, and falls to a powder of bicarbonate: $\text{NH}_4 \text{O}, \text{CO}_2 + \text{H O}, \text{CO}_2$.

Carbonate of baryta occurs native, as witherite. It forms, when artificially prepared, a heavy white powder, soluble in diluted hydrochloric and nitric acids, insoluble in water. It is very poisonous. Formula, $\text{Ba O}, \text{CO}_2$.

Carbonate of strontia resembles the preceding. It occurs native, as strontianite, in radiated crystalline masses of an apple-green color. It is not poisonous. Formula, $\text{Sr O}, \text{CO}_2$.

Carbonate of lime occurs native, as marble, limestone, chalk, and calcareous spar. It also forms the chief part of shells, and is often found in springs, dissolved by an excess of carbonic acid. When such water, which is very hard water, is boiled, the excess of carbonic acid escapes, the carbonate of lime is deposited, and the water becomes, *pro tanto*, softer. Or, the same effect may be produced by adding just as much lime-water as will neutralize the bicarbonate of lime, when the whole is precipitated as neutral carbonate: $\text{Ca O}, 2 \text{CO}_2 + \text{Ca O} = 2 (\text{Ca O}, \text{CO}_2)$.

When carbonate of lime is ignited in the open fire, it loses all its carbonic acid and becomes quick-lime. The uses of this substance are well known. Formula of carbonate of lime, $\text{Ca O}, \text{CO}_2$.

Carbonate of magnesia, $\text{Mg O}, \text{CO}_2$, occurs as a rock in the East Indies. When a solution of bicarbonate is exposed to the air, crystals are deposited, which are $\text{Mg O}, \text{CO}_2 + 3 \text{aq.}$ Other crystals have been obtained, which were $\text{Mg O}, \text{CO}_2 + 5 \text{aq.}$ When carbonate of potash is added to a solution of sulphate of magnesia, a precipitate falls, which contains $4 \text{Mg O} + 3 \text{CO}_2 + 4 \text{aq.}$

Carbonate of protoxide of iron is formed when an alkaline carbonate is added to a solution of protosulphate of iron. It falls as

a dirty white bulky precipitate, which rapidly becomes green, and then brown, losing carbonic acid, and attracting oxygen, till it passes into hydrated peroxide of iron. It may be preserved as protocarbonate by mixing the fresh precipitate while still moist with sugar, and drying it in the water bath. In this state it is the carbonas ferri saccharatus, and is a very active remedy. It occurs in chalybeate waters, dissolved by excess of carbonic acid. Formula, $\text{Fe O, C O}_2 + \text{aq.}$

There are two native carbonates of copper: the dicarbonate, $2 \text{ Cu O} + \text{C O}_2 + \text{aq.}$ in the beautiful green mineral called malachite; and the carbonate, hydrated, in the fine blue copper ore, $\text{Cu O, H O} + 2 (\text{Cu O, C O}_2)$.

Carbonate of lead, Pb O, C O_2 , occurs native as white lead spar. Prepared artificially, it is ceruse, or white lead, much used as a white pigment. It is formed by the slow action of air, moisture, and the vapor of acetic acid on thin sheets of lead, by which the metal is oxidized and carbonated. It is the most poisonous of all the compounds of lead, and is apt to be formed when pure water (as rain water) is kept in leaden cisterns or conveyed in leaden pipes. It is not formed, however, when the water contains even a small proportion of saline matter, especially sulphates. These appear to protect the metal, and render the use of it safe.

SULPHUR SALTS.

Berzelius has shown that sulphides unite together, and produce what he calls sulphur salts. The sulphides of potassium, sodium, and the strongly basic metals in general, act the part of bases; and the sulphides of arsenic, antimony, molybdenum, &c., take the parts of acids. Thus sesquisulphide of arsenic combines with sulphide of potassium, forming the arsenio-sulphide of potassium, $\text{K S} + \text{As S}_2$, which corresponds to the arsenite of potash, $\text{K O} + \text{As O}_2$; and as a general rule, the sulphur salts correspond to oxygen salts, and may of course be represented in two ways; as, if we make the arsenite of potash $\text{K} + \text{As O}_4$, the sulphur salt will be $\text{K} + \text{As S}_4$. The sulphides of hydrogen and carbon are sulphur acids. The sulphur salts, as yet, are not of much practical interest, although the tendency to form them is applied to useful purposes in analysis.

Selenium and tellurium form similar compounds.

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